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Region 10

DREDGED MATERIAL MANAGEMENT PLAN AND ENVIRONMENTAL IMPACT STATEMENT

McNary Reservoir and Lower Snake River Reservoirs

APPENDIX H
Water and Sediment Quality

FINAL
July 2002

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13. ABSTRACT *(Maximum 200 words)*
This final Dredged Material Management Plan/Environmental Impact Statement (DMMP/EIS) presents the Corps of Engineers' programmatic plan for maintenance of the authorized navigation channel and certain publicly owned facilities in the lower Snake River reservoirs between Lewiston, Idaho and the Columbia River, and McNary reservoir on the Columbia River for 20 years; for management of dredged material from these reservoirs; and for maintenance of flow conveyance capacity at the most upstream extent of the Lower Granite reservoir for the remaining economic life of the dam and reservoir project (to year 2074). The Corps, along with the U.S. Environmental Protection Agency, analyzed four alternatives for this Final DMMP/EIS: Alternative 1 - No Action (No Change) - Maintenance Dredging With In-Water Disposal; Alternative 2 - Maintenance Dredging With In-Water Disposal to Create Fish Habitat and a 3-Foot Levee Raise; Alternative 3 - Maintenance Dredging With Upland Disposal and a 3-Foot Levee Raise; and Alternative 4 - Maintenance Dredging With Beneficial Use of Dredged Material and a 3-Foot Levee Raise (Recommended Plan/Preferred Alternative).

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DREDGED MATERIAL MANAGEMENT PLAN AND ENVIRONMENTAL IMPACT STATEMENT

McNARY RESERVOIR AND LOWER SNAKE RIVER RESERVOIRS

APPENDIX H

WATER AND SEDIMENT QUALITY

U.S. Army Corps of Engineers
Walla Walla District
201 N. 3rd Avenue
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TABLE OF CONTENTS

Page

1.0 INTRODUCTION H-1
2.0 WATER QUALITY H-1
  2.1 Water Temperature H-1
    2.1.1 Snake River H-1
    2.1.2 Columbia River H-3
    2.1.3 Clearwater River H-4
  2.2 Dissolved Oxygen H-5
  2.3 Total Suspended Solids H-6
  2.4 Nutrients H-7
    2.4.1 Nitrogen H-7
    2.4.2 Phosphorus H-8
    2.4.3 Ammonia H-10
  2.5 Food Base H-12
    2.5.1 Phytoplankton H-14
    2.5.2 Zooplankton
  2.6 Benthic Macroinvertebrates H-15
3.0 SEDIMENT QUALITY H-15
  3.1 Review of Sediment Quality Data Obtained for Feasibility Study H-15
    3.1.1 Chemical Analysis of Sediment Samples H-16
    3.1.2 Chemical Analysis of Elutriates H-26
  3.2 Sediment Sampling in the Proposed and Possible Future Dredging Sites H-29
  3.3 Summary of Results H-36
4.0 REFERENCES H-36

List of Figures

Figure H-1 Dissolved Oxygen for Select Stations in 1997 .... H-5
Figure H-2 Dissolved Oxygen Profiles for Select Days in 1994, 1995, and 1997 at Lower Granite Forebay Station H-6
Figure H-3 Total Suspended Solids for Selected Sampling Stations in 1997 .... H-7
Figure H-4 Total Nitrogen for Selected Sampling Stations in 1997 .... H-8
Figure H-5 Phosphorous for Selected Sampling Stations in 1997 .... H-9
Figure H-6 Chlorophyll *a* for Selected Sampling Stations in 1997 .... H-13
Figure H-7 Mean Concentrations and 95 Percent Confidence Limits of In-river Water and In-sediment Elutriate at Ambient pH H-29

List of Tables

Table H-1 Lower Granite Tailrace Temperature Data for Water Year 2000 .... H-2
Table H-2 Ice Harbor Tailrace Temperature Data for Water Year 2000 .... H-2
Table H-3 Snake River at Anatone, Temperature Data for Water Year 2000 .... H-3
Table H-4 McNary Tailrace Water Temperature Data for Water Year 2000 .... H-4

TABLE OF CONTENTS (CONTINUED)

Page

List of Tables (Continued)

Table H-5	Clearwater River at Spalding, Temperature Data for Water Year 2000	H-4
Table H-6	Ammonia (mg/L) Chronic Criteria for the Protection of Salmonids and Fish Early Life Stages	H-11
Table H-7	Ammonia (mg/L) Acute Criteria for Salmonids Absent or Present	H-12
Table H-8	Summary of Sieve Test Results for Sediment Samples Collected from the Lower Snake River in 1997	H-16
Table H-9	Summary of Average Glyphosate AMPA Concentrations (μg/L) for Sediment Samples Collected during 1997 in the Lower Snake River	H-18
Table H-10	Summary of Average Concentrations (ppb) of Organochlorine Pesticides and TPH in Sediments Collected during 1997 in the Lower Snake River	H-18
Table H-11	Summary of Mean Metal Concentrations for Sediment Samples Collected (1997) in the Lower Snake River for the LSRJSMFS	H-22
Table H-12	Comparison of Metal Concentrations in Eastern Washington (Minimum, Mean, and Maximum) to the State Wide Mean	H-23
Table H-13	Summary of Mean Nutrient Concentrations for Sediment Samples Collected in the Lower Snake River	H-25
Table H-14	Summary of Mean Metal Concentrations for Ambient pH Elutriate Samples Collected in the Lower Snake River Project	H-26
Table H-15	Summary of Mean Nutrient Concentrations for Ambient pH Elutriate Samples Collected during Phase 2 (1997) in the Lower Snake River	H-27
Table H-16	List of Parameters Analyzed with Method EPA 8270C	H-30
Table H-17	List of Compounds Analyzed with Method 8290	H-32
Table H-18	List of Compounds Analyzed with Method 8141	H-32
Table H-19	List of Compounds Analyzed with Method 8151A	H-33
Table H-20	List of Compounds Analyzed with Method 6010	H-33
Table H-21	Constituent Properties of Samples from the Proposed Dredging Sites	H-35

1.0 INTRODUCTION

This appendix includes reviews of water quality and sediment data as it pertains to the Lower Snake River Reservoirs and the McNary Reservoir on the Columbia River. The text has been updated and corrected to reflect public and agency comments received on the Draft DMMP/EIS. Some of the information and tables shown in the earlier draft appendix incorrectly compared data collected outside of the proposed dredging sites with screening criteria for areas to be dredged; and therefore, were deleted in this update. Information pertaining to water quality and sediment focuses on data collected between 1994 and 2000.

2.0 WATER QUALITY

Information for the Columbia, Snake, and Clearwater Rivers from the *Final Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement* (LSRJSMFR/EIS) *Water Quality Appendix* (Corps, 2002) has been used in this appendix and the complete text is incorporated by reference to provide an overview of the general water quality conditions within these reservoir projects. Data that has been collected specifically for past dredging work has been used to define conditions within those areas that are proposed for possible future dredging. Section 2.1 provides a summary of water temperatures in the three rivers while Sections 2.2 through 2.6 summarize other water quality data that had been presented in the "Lower Snake River Juvenile Salmon Migration Feasibility Report/Environmental Impact Statement". This information is presented to give an overview of the general water quality conditions within the McNary and Lower Snake Reservoirs without regard to whether or not those areas are within the proposed or possible future dredging boundaries.

2.1 WATER TEMPERATURE

Water temperature in the study area varies by time of year and location. Generally, water temperature is lower in the winter months of January and February, increases slowly during spring runoff (March to May), increases more rapidly in late spring until mid-summer (June to early August), plateaus through mid-September, then decreases steadily through January. For the purposes of illustration, the year 2000 has been used in Sections 3.1 through 3.3 as a typical representation of water temperatures in the Lower Snake, Columbia, and Clearwater Rivers. The period for the normal dredging window (December through February) typically contains the coldest water temperatures during the year. The following temperature summaries outline water temperatures for the full year so they can be compared to the winter dredging period.

2.1.1 Snake River

In the Snake River at the Lower Granite Lock and Dam (Lower Granite) tailrace in water year 2000 (October 1999 to September 2000), the average monthly water temperatures in January and February were 39.0 and 39.4 °F (3.9 and 4.1 °C) with a maximum daily temperature of 41.4 °F (5.2 °C) and a minimum daily temperature of 37.2 °F (2.9 °C). Conversely, average monthly temperatures in July through September in 2000 were 66.0, 64.9, and 65.1 °F (18.9, 18.3, and 18.4 °C), respectively. The maximum daily value for this period was 68.0 °F (20.0 °C) and the lowest was 61.9 °F (16.6 °C) (table H-1). Water temperatures in the Ice Harbor Lock and Dam

AQM03-06-1256

(Ice Harbor) tailrace were comparable to those in Lower Granite; however, Ice Harbor water temperatures were warmer on average throughout the year (table H-2). Because temperatures were similar at the farthest extents of the study area, data for the other Snake River reservoirs were assumed to follow similar trends. Average daily variation refers to the difference between maximum and minimum temperatures on a daily basis and averaged for the month designated.

Table H-1. Lower Granite Tailrace Temperature Data for Water Year 2000.

	Monthly Average	Daily Max.	Daily Min.	Average Daily Variation
October	58.3 °F (14.6 °C)	63.3 °F (17.4 °C)	53.2 °F (11.8 °C)	0.4 °F (0.2 °C)
November	50.2 °F (10.1 °C)	53.2 °F (11.8 °C)	46.0 °F (7.8 °C)	0.4 °F (0.2 °C)
December	42.6 °F (5.9 °C)	46.0 °F (7.8 °C)	40.6 °F (4.8 °C)	0.4 °F (0.2 °C)
January	39.0 °F (3.9 °C)	40.1 °F (4.5 °C)	37.9 °F (3.3 °C)	0.2 °F (0.1 °C)
February	39.4 °F (4.1 °C)	41.4 °F (5.2 °C)	37.2 °F (2.9 °C)	0.4 °F (0.2 °C)
March	43.7 °F (6.5 °C)	47.3 °F (8.5 °C)	41.4 °F (5.2 °C)	0.4 °F (0.2 °C)
April	49.3 °F (9.6 °C)	52.3 °F (11.3 °C)	46.2 °F (7.9 °C)	0.7 °F (0.4 °C)
May	53.6 °F (12.0 °C)	57.0 °F (13.9 °C)	50.7 °F (10.4 °C)	0.5 °F (0.3 °C)
June	59.7 °F (15.4 °C)	66.0 °F (18.9 °C)	53.6 °F (12.0 °C)	0.9 °F (0.5 °C)
July	66.0 °F (18.9 °C)	68.0 °F (20.0 °C)	63.9 °F (17.7 °C)	0.9 °F (0.5 °C)
August	64.9 °F (18.3 °C)	67.3 °F (19.6 °C)	61.9 °F (16.6 °C)	1.4 °F (0.8 °C)
September	65.1 °F (18.4 °C)	67.5 °F (19.7 °C)	62.1 °F (16.7 °C)	0.7 °F (0.4 °C)
Source: Corps, 2001				

Table H-2. Ice Harbor Tailrace Temperature Data for Water Year 2000.

	Monthly Average	Daily Max.	Daily Min.	Average Daily Variation
October	61.5 °F (16.4 °C)	66.7 °F (19.3 °C)	56.1 °F (13.4 °C)	3.2 °F (1.8 °C)
November	54.0 °F (12.2 °C)	58.6 °F (14.8 °C)	49.5 °F (9.7 °C)	2.7 °F (1.5 °C)
December	47.3 °F (8.5 °C)	51.6 °F (10.9 °C)	41.7 °F (5.4 °C)	3.2 °F (1.8 °C)
January	40.3 °F (4.6 °C)	44.6 °F (7.0 °C)	37.9 °F (3.3 °C)	1.8 °F (1.0 °C)
February	39.7 °F (4.3 °C)	42.8 °F (6.0 °C)	38.1 °F (3.4 °C)	1.4 °F (0.8 °C)
March	44.8 °F (7.1 °C)	49.3 °F (9.6 °C)	40.6 °F (4.8 °C)	2.9 °F (1.6 °C)
April	51.3 °F (10.7 °C)	54.1 °F (12.3 °C)	45.7 °F (7.6 °C)	2.7 °F (1.5 °C)
May	56.3 °F (13.5 °C)	63.3 °F (17.4 °C)	52.0 °F (11.1 °C)	3.1 °F (1.7 °C)
June	61.7 °F (16.5 °C)	67.5 °F (19.7 °C)	57.0 °F (13.9 °C)	3.2 °F (1.8 °C)
July	69.4 °F (20.8 °C)	72.9 °F (22.7 °C)	63.3 °F (17.4 °C)	3.6 °F (2.0 °C)
August	69.1 °F (20.6 °C)	72.9 °F (22.7 °C)	63.3 °F (17.4 °C)	6.8 °F (3.8 °C)
September	67.1 °F (19.5 °C)	71.2 °F (21.8 °C)	62.8 °F (17.1 °C)	3.8 °F (2.1 °C)
Source: Corps, 2001				

Temperatures measured at the U.S. Geological Survey (USGS) gage at Anatone [Snake River Mile (RM) 167.2] give some indication of the Snake River water temperature entering the Lewiston area. These temperatures range from an average maximum of about 37.4 °F (3 °C) in February to about 72.5 °F (22.5 °C) in mid-July (Corps, 1999). In addition, in water year 2000,

the lowest daily maximum temperature of 41.0 °F (5 °C) and lowest daily minimum of 36.5 °F (2.5 °C) were both recorded in January. Conversely, the highest maximum temperature of 75.7 °F (24.3 °C) and highest minimum temperature of 66.6 °F (19.2 °C) occurred in August (table H-3).

Table H-3. Snake River at Anatone, Temperature Data for Water Year 2000.

	Monthly Average	Daily Max	Daily Min	Average Daily Variation
October		63.5 °F (17.5 °C)	52.7 °F (11.5 °C)	1.4 °F (0.8 °C)
November		53.6 °F (12.0 °C)	43.7 °F (6.5 °C)	0.9 °F (0.5 °C)
December		46.4 °F (8.0 °C)	38.3 °F (3.5 °C)	0.9 °F (0.5 °C)
January		41.0 °F (5.0 °C)	36.5 °F (2.5 °C)	0.7 °F (0.4 °C)
February		43.7 °F (6.5 °C)	37.4 °F (3.0 °C)	0.9 °F (0.5 °C)
March	46.0 °F (7.8 °C)	48.6 °F (9.2 °C)	43.7 °F (6.5 °C)	1.6 °F (0.9 °C)
April	51.4 °F (10.8 °C)	55.4 °F (13.0 °C)	46.9 °F (8.3 °C)	1.8 °F (1.0 °C)
May	55.8 °F (13.2 °C)	60.3 °F (15.7 °C)	52.2 °F (11.2 °C)	1.8 °F (1.0 °C)
June	62.2 °F (16.8 °C)	70.0 °F (21.1 °C)	53.8 °F (12.1 °C)	2.2 °F (1.2 °C)
July	70.0 °F (21.1 °C)	74.8 °F (23.8 °C)	64.6 °F (18.1 °C)	2.2 °F (1.2 °C)
August	71.1 °F (21.7 °C)	75.7 °F (24.3 °C)	66.6 °F (19.2 °C)	3.4 °F (1.9 °C)
September	66.2 °F (19.0 °C)	74.7 °F (23.7 °C)	55.2 °F (12.9 °C)	3.2 °F (1.8 °C)
Source: Corps, 2001				

2.1.2 Columbia River

Water temperature in the McNary Lock and Dam (McNary) tailrace for water year 2000 follows the same pattern exhibited by the Snake River reservoirs and varies by time of year and location. Generally, water temperature is lower in the winter months of January and February, increases slowly during spring runoff (March to May), increases more rapidly in late spring until mid-summer (June to early August), plateaus through mid-September, then decreases steadily through January (table H-4). The average monthly temperatures in January and February were 40.1 and 38.8 °F (4.5 and 3.8 °C), respectively. The average monthly temperatures in July and August were 66.2 and 69.3 °F (19 and 20.7 °C), respectively.

Table H-4. McNary Tailrace Water Temperature Data for Water Year 2000.

	Monthly Average	Daily Max.	Daily Min.	Average Daily Variation
October	59.0 °F (15.0 °C)	62.1 °F (16.7 °C)	54.3 °F (12.4 °C)	0.4 °F (0.2 °C)
November	52.3 °F (11.3 °C)	54.3 °F (12.4 °C)	48.9 °F (9.4 °C)	0.4 °F (0.2 °C)
December	45.7 °F (7.6 °C)	48.9 °F (9.4 °C)	42.6 °F (5.9 °C)	0.2 °F (0.1 °C)
January	40.1 °F (4.5 °C)	42.4 °F (5.8 °C)	37.9 °F (3.3 °C)	0.5 °F (0.3 °C)
February	38.8 °F (3.8 °C)	39.9 °F (4.4 °C)	37.9 °F (3.3 °C)	0.4 °F (0.2 °C)
March	42.3 °F (5.7 °C)	45.5 °F (7.5 °C)	39.4 °F (4.1 °C)	0.7 °F (0.4 °C)
April	48.7 °F (9.3 °C)	51.4 °F (10.8 °C)	44.8 °F (7.1 °C)	1.1 °F (0.6 °C)
May	54.7 °F (12.6 °C)	58.5 °F (14.7 °C)	50.4 °F (10.2 °C)	1.1 °F (0.6 °C)
June	60.4 °F (15.8 °C)	64.8 °F (18.2 °C)	56.5 °F (13.6 °C)	1.3 °F (0.7 °C)
July	66.2 °F (19.0 °C)	69.3 °F (20.7 °C)	63.7 °F (17.6 °C)	0.9 °F (0.5 °C)
August	69.3 °F (20.7 °C)	70.9 °F (21.6 °C)	67.6 °F (19.8 °C)	0.9 °F (0.5 °C)
September	65.7 °F (18.7 °C)	69.1 °F (20.6 °C)	62.1 °F (16.7 °C)	1.1 °F (0.6 °C)
Source: Corps, 2001				

2.1.3 Clearwater River

Temperatures measured at the USGS gage at Spalding (Clearwater RM 11.6) give some indication of the Clearwater River water temperature in the Lewiston area. In water year 2000, the lowest daily maximum temperatures of 41.9 °F (5.5 °C) and the lowest daily minimum temperature of 35.6 °F (2.0 °C) were recorded in January. Conversely, the highest maximum temperature of 67.3 °F (19.6 °C) occurred in June and highest minimum temperature of 53.6 °F (12.0 °C) occurred in July (table H-5).

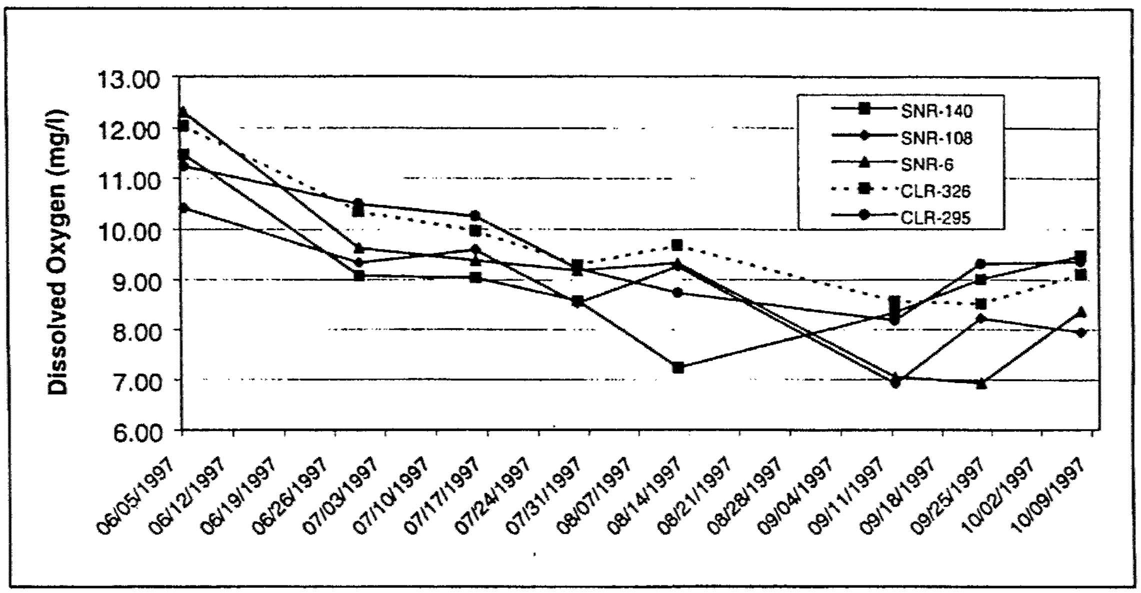
Table H-5. Clearwater River at Spalding, Temperature Data for Water Year 2000.

	Monthly Average	Daily Max.	Daily Min.	Average Daily Variation
October		55.4 °F (13.0 °C)	45.5 °F (7.5 °C)	3.6 °F (2.0 °C)
November		50.9 °F (10.5 °C)	40.1 °F (4.5 °C)	2.0 °F (1.1 °C)
December		43.7 °F (6.5 °C)	36.5 °F (2.5 °C)	1.1 °F (0.6 °C)
January		41.9 °F (5.5 °C)	35.6 °F (2.0 °C)	2.0 °F (1.1 °C)
February		43.7 °F (6.5 °C)	37.4 °F (3.0 °C)	2.0 °F (1.1 °C)
March	44.6 °F (7.0 °C)	48.6 °F (9.2 °C)	41.2 °F (5.1 °C)	3.4 °F (1.9 °C)
April	46.4 °F (8.0 °C)	50.5 °F (10.3 °C)	43.3 °F (6.3 °C)	2.5 °F (1.4 °C)
May	50.5 °F (10.3 °C)	56.8 °F (13.8 °C)	45.7 °F (7.6 °C)	2.3 °F (1.3 °C)
June	57.6 °F (14.2 °C)	67.3 °F (19.6 °C)	49.3 °F (9.6 °C)	3.1 °F (1.7 °C)
July	57.2 °F (14.0 °C)	62.6 °F (17.0 °C)	53.6 °F (12.0 °C)	4.5 °F (2.5 °C)
August	55.0 °F (12.8 °C)	62.1 °F (16.7 °C)	50.7 °F (10.4 °C)	4.9 °F (2.7 °C)
September	57.7 °F (14.3 °C)	64.9 °F (18.3 °C)	50.5 °F (10.3 °C)	4.1 °F (2.3 °C)
Source: Corps, 2001				

2.2 DISSOLVED OXYGEN

Figure H-1 presents a comparison of dissolved oxygen (DO) data throughout the project area for selected stations sampled in 1997. The values represent DO concentrations averaged over the entire water column. In contrast to water temperatures, the highest DO concentrations are typically observed during spring runoff and tend to decline with increasing temperature.

For the two Columbia River stations (CLR-326 and CLR-295), DO levels were consistently above 8 parts per million (ppm) (8 mg/L) over the entire sampling period. At the lower Snake River stations, DO concentrations were, for the most part, above 8 ppm (8.0 mg/L) during 1997 except at SNR-140 in mid August, at SNR-108 and SNR-6 during mid-September, and at SNR-6 in late September. The timing of the seasonal low level seemed to occur first upstream and then progressively moved downstream. A review of data collected in other years, particularly during the historically low flow conditions in 1994, reveal only minor differences from the indicated trends.

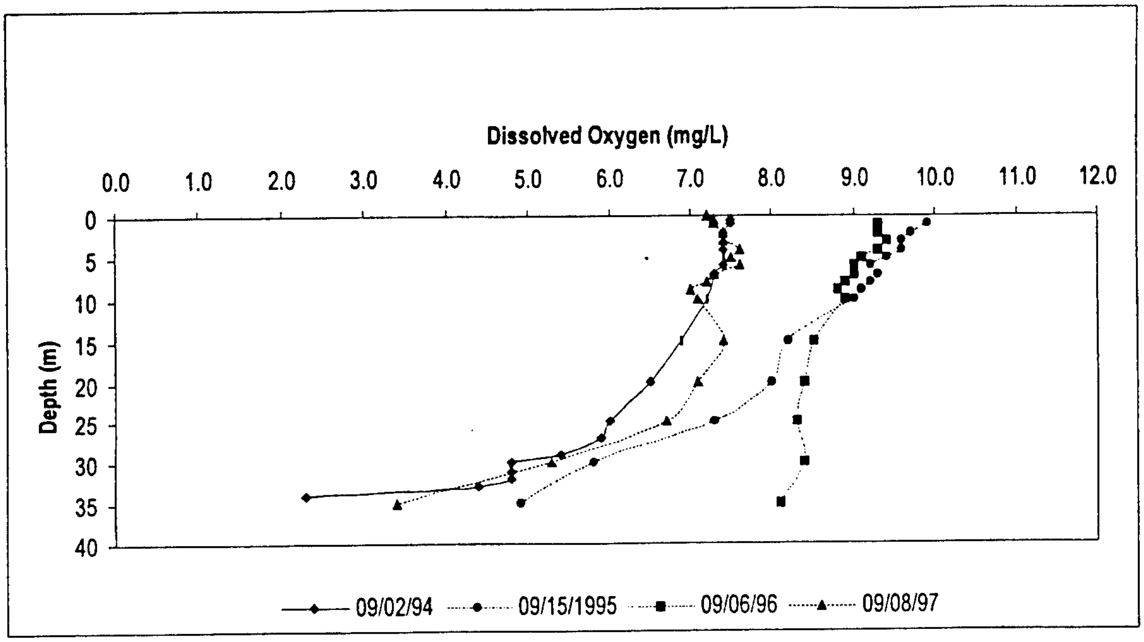


Source: Corps, 1999

Figure H-1. Dissolved Oxygen for Select Stations in 1997.

A few locations had lower DO concentrations at depth on some sample dates. The station in the deepest area in Lower Granite reservoir (SNR-108) had low readings of 5.3 and 3.4 ppm (5.3 and 3.4 mg/L) or 59 and 38 percent saturation at depths of 32.8 and 38.3 yards [30 and 35 meters (m)], respectively, on 8 September 1997 (figure H-2). At depths less than 21.9 yards (20 m), DO levels ranged from 7.0 to 7.6 ppm (7.0 to 7.6 mg/L) or 80 to 87 percent saturation. In 1994 and 1995, the lowest readings recorded for this same station at a depth of 37.2 yards (34 m) were 2.3 and 4.9 ppm (2.3 and 4.9 mg/L), respectively. A comparison of DO data collected in 1975 and 1977 at approximately the same time of year suggests that concentrations of DO at depth have decreased over time.

A location in Little Goose reservoir just below the confluence of Deadman Creek also showed relatively low values of 5.5 and 4.7 ppm (5.5 and 4.7 mg/L) or 62 and 52 percent saturation at depths of 10.9 and 32.8 yards (10.0 and 30.0 m), respectively, during early September 1997. Above 10.9 yards (10 m), DO levels ranged between 5.8 to 7.2 ppm (5.8 to 7.2 mg/L) or 67 to 84 percent saturation. Prior to the early September period of low DO, and for the remainder of the season (starting in early October), DO concentrations at all the Snake River stations were near or above 90 percent of saturation.

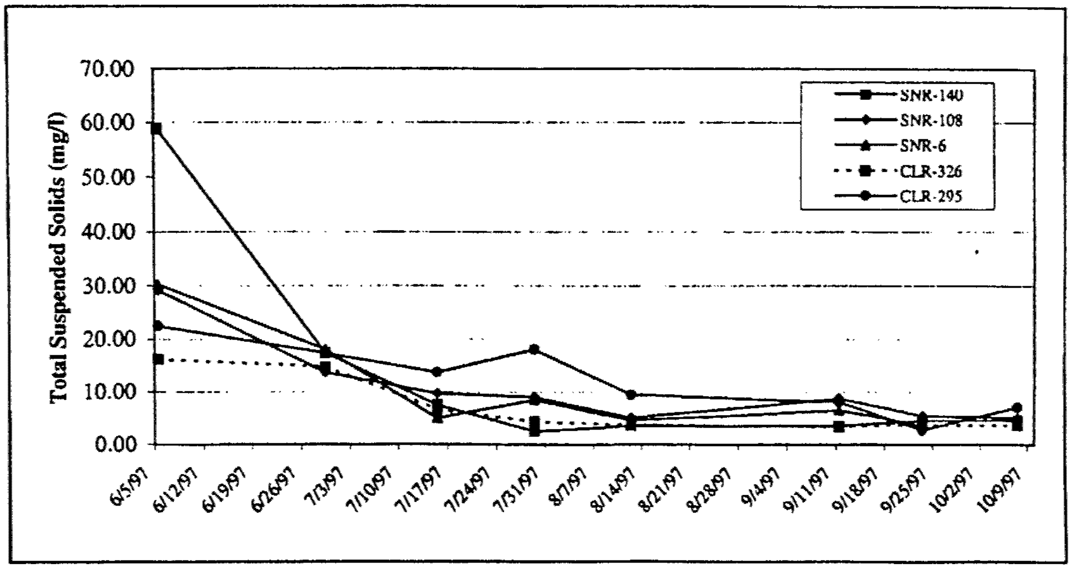


Source: Corps, 1999

Figure H-2. Dissolved Oxygen Profiles for Select Days in 1994, 1995, and 1997 at Lower Granite Forebay Station.

2.3 TOTAL SUSPENDED SOLIDS

Typically, total suspended solids (TSS) concentrations are highest during spring runoff and then decline as flows diminish through late summer and into fall. Figure H-3 shows the 1997 TSS concentrations averaged over depth for selected stations. The highest TSS levels were observed during May and early June sampling events when flows were highest and then dramatically decreased with most stations having less than 10 ppm (10 mg/L) for the remainder of the season.



Source: Corps, 1999

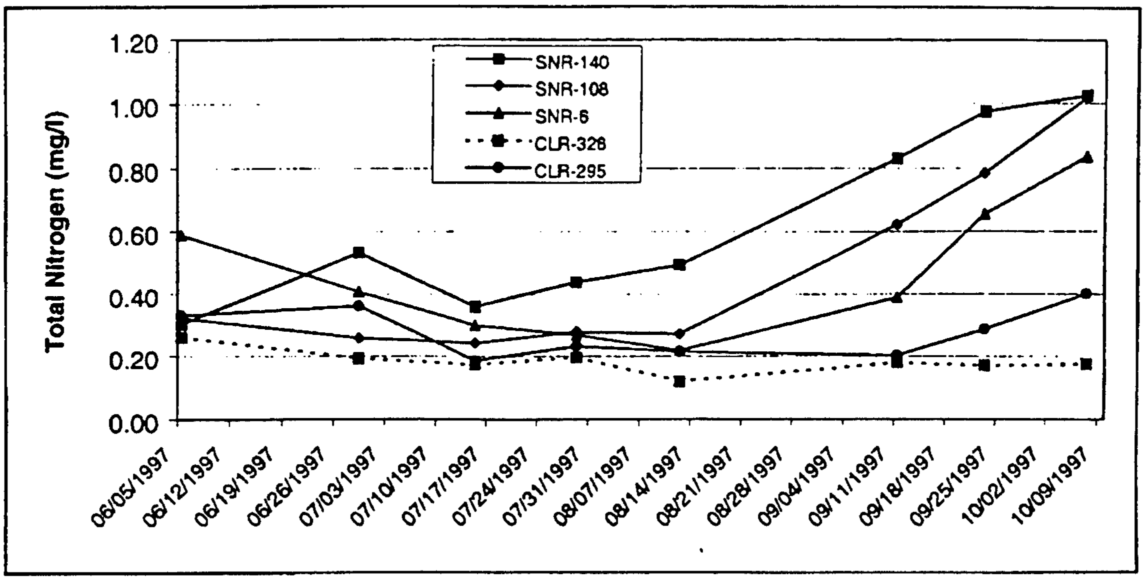
Figure H-3. Total Suspended Solids for Selected Sampling Stations in 1997.

2.4 NUTRIENTS

2.4.1 Nitrogen

Of the various soluble inorganic forms of nitrogen, nitrate plus nitrite ($NO_3 + NO_2$) was the principal component, often comprising more than 90 percent of the soluble fraction. Nitrate-nitrogen concentrations exhibited variations at several of the sites, but long-term trends were not apparent. Nitrate concentrations were consistently greater than ammonia values at almost all stations. Two upstream lower Snake River locations had median NO_3 levels that were much higher, ranging between 0.33 and 0.35 ppm (0.33 and 0.35 mg/L), while the median NO_3 levels throughout the lower Snake River reach ranged from 0.13 to 0.19 ppm (0.13 to 0.19 mg/L). These data suggest that the high levels contributed from the middle Snake River reach are slightly diluted by the low levels in the Clearwater River, resulting in moderately high NO_3 levels in the lower Snake River. The Columbia River stations generally had lower NO_3 levels than those observed in the lower Snake River with median concentrations ranging between 0.07 and 0.13 ppm (0.07 and 0.13 mg/L).

Total nitrogen (total-N) levels, which include both the inorganic and organic components, were relatively high in the Snake River stations. In general, concentrations decreased along the lower Snake River during 1997, but were still higher than those found in the Columbia River (figure-H-4). In the spring and summer, the total-N levels increased from about 0.30 to 0.60 ppm (0.30 to 0.60 mg/L) at the lower Snake River stations. The total-N levels increased considerably in the fall with peak levels at the Snake River stations reaching 0.8 to 1.1 ppm (0.8 to 1.1 mg/L) in October. This late season increase may be due to a reduction in plant uptake associated with aquatic plant and algae dying back or going dormant as well as agricultural harvesting in the watershed. Early fall rains after prolonged dry periods can also increase nutrient concentrations. However, a corresponding increase in TSS levels was not detected.



Source: Corps, 1999

Figure H-4. Total Nitrogen for Selected Sampling Stations in 1997.

2.4.2 Phosphorus

Phosphorus is generally expressed in terms of total phosphorus and ortho-phosphorus. Ortho-phosphorus (ortho-P) represents the inorganic soluble fraction of the total phosphorus in water and is generally considered to be more readily available for biological uptake than is total phosphorus. Total phosphorus (TP) consists of both the soluble fraction and that portion adsorbed to sediments or tied up with biological materials in the water column. Since phosphorus readily attaches to and travels with sediments, adsorbed or biological quantities usually represent the largest portion of TP. In low-oxygen conditions, the adsorption bond between phosphorus and the sediment particle becomes unstable and often results in a release of the adsorbed phosphorus into the water column. In contrast to nitrogen, phosphorus is usually the limiting nutrient for plant growth in freshwater systems. However, N:P ratios in the lower Snake River, which range from 9 to 11, are inconclusive with respect to the rate limiting nutrient. Therefore, it is unclear whether substantial increases in phosphorus levels would lead to increased algal productivity and macrophyte growth.

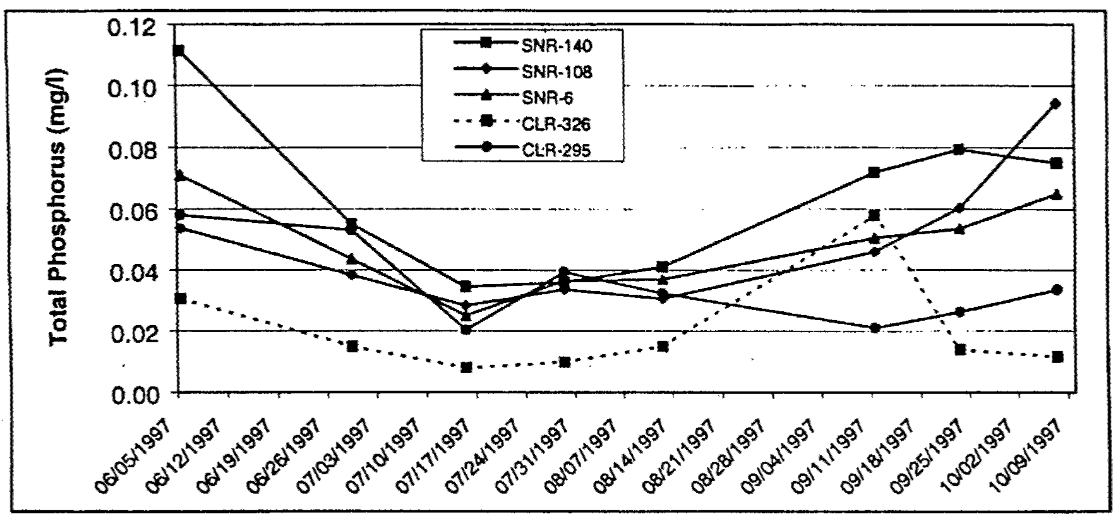
Recent and historical data suggest that ortho-P levels in the lower Snake River tend to be highest in the spring and fall, with relatively low concentrations in the summer. The lower levels during the summer are most likely due to biological uptake by phytoplankton. As growth diminishes in the fall, the phosphorus levels increase, which was most evident at the reservoir stations where algal growth is usually most abundant. In the Columbia River ortho-P concentrations were usually below 0.008 ppm (0.008 mg/L) and there was little change in the levels during the sampling season. Throughout the lower Snake reach, ortho-P levels through mid-August peaked at 0.018 ppm (0.018 mg/L) and increased to 0.022 to 0.063 ppm (0.022 to 0.063 mg/L) from mid-September through October.

During early June of 1997, TP levels (water column average) throughout the lower Snake River ranged from around 0.060 to 0.11 ppm (0.060 to 0.11 mg/L) (figure H-5). The high TP levels

during this time of year are most likely attributable to the suspended sediment contained in the peak flow period. For much of the 1997 growing season, TP levels generally ranged from 0.025 to 0.060 ppm (0.025 to 0.060 mg/L) and then steadily increased in the fall. Similar concentrations were observed in 1994 and 1995, where concentrations ranged from 0.025 to 0.060 ppm (0.025 to 0.060 mg/L) in the summer and then increased to around 0.09 ppm (0.09 mg/L) in the fall. In September, the TP levels steadily increased, with levels in the lower Snake River ranging between 0.05 and 0.10 ppm (0.05 and 0.10 mg/L).

According to the Washington State water quality standards, TP levels above 0.020 and 0.035 ppm (0.020 and 0.035 mg/L) are considered to be critical thresholds in terms of preventing excessive algal growth when ambient trophic conditions are considered to be in the lower and upper mesotrophic categories, respectively. Oligotrophic conditions represent high quality waters with good water clarity and low algal production and eutrophic conditions represent high nutrient levels, excessive algal growth, and poor water clarity. Mesotrophic conditions are somewhere in the middle and typically represent moderate levels of algal production, water clarity, and light transparency.

Limnological conditions in the lower Snake River impoundments have generally been considered to be in the upper mesotrophic to eutrophic category. Based on a review of the 1997 data, the average phosphorus levels throughout lower Snake River appear to be in the 0.030 to 0.040 ppm (0.030 to 0.040 mg/L) range during the mid-summer and slightly higher to near the 0.060 to 0.070 ppm (0.060 to 0.070 mg/L) range during June and the fall months. This would suggest that the average phosphorus levels in the lower Snake River for much of the entire growing season would likely be above the Washington Department of Ecology phosphorus guideline of 0.035 ppm (0.035 mg/L) that was established to maintain existing conditions and prevent eutrophic conditions.



Source: Corps, 1999

Figure H-5. Phosphorous for Selected Sampling Stations in 1997.

2.4.3 Ammonia

Most of the studies dealing with sediment quality referenced in the LSRJSMFR/EIS describe the sediment as very rich in nitrogenous compounds. The dominant species of nitrogen in the sediment is ammonia. In the water, nitrite/nitrate (NO_2 + NO_3) is the dominant species of nitrogen if the water is well oxygenated and the proportion of nitrite is small. Nitrite is an intermediate oxidation state of nitrogen, which can be in the form of nitrate, nitrite, or ammonia ions depending on oxidation state.

The sediments contain high amounts of ammonia [60 to 80 ppm (60 to 80 mg/L) average] but it is not fully understood how the nitrogen cycle works in the Snake River reservoirs. The lower Snake River had average water nitrite/nitrate levels from 0.13 to 0.35 ppm (0.13 to 0.35 mg/L). The water ammonia levels were near instrument detection limits in some cases or below detection limit [0.007 ppm (0.007 mg/L) N as NH_3]. This suggests the ammonia is probably bound to the sediments. Unless it is exposed, the little ammonia that is naturally released is generally oxidized quickly.

Ammonium (NH_4^+) is the ionized form of ammonia and is generally only toxic in very high concentrations. It is the un-ionized portion of ammonia (NH_3) that is toxic to aquatic life (Downing and Merkens, 1955). Un-ionized ammonia is more toxic because it is a neutral molecule and, thus, has the ability to diffuse across the epithelial membranes of aquatic organisms far more readily than a charged ion. In nature, ammonia is a byproduct of the organism's biological processes and must be excreted. High external un-ionized ammonia concentrations reduce or reverse diffusive gradient and cause the buildup of ammonia in gill tissue of fish (EPA, 1999). Research on various forms of aquatic life indicates that unionized ammonia toxicity positively correlated to temperature (Nimmo et al., 1989) and pH (Tabata, 1962; Armstrong et al., 1978), especially in hard water (Johnson, 1995).

There is a potential for both acute (short-term exposure) and chronic (long-term exposure) effects from un-ionized ammonia in the Snake River (Corps, 1999). The Snake River has relatively hard water based on the concentration of calcium carbonate and magnesium carbonate. Depending on the temperature, flow pattern, pH, and hardness, there could be toxic effects to aquatic life. Performance of the work during the coldest months would help to minimize potential effects of ammonia. Close water quality monitoring will help determine any increases in ammonia concentration and steps then can be taken to reduce the impacts and modify the operation to reduce ammonia production.

Table H-6 presents the Environmental Protection Agency (EPA) limits for ammonia concentration for chronic exposure of aquatic species. Values in the table are the criterion continuous concentration (CCC) values that define the upper limit of ammonia concentration that aquatic species can be exposed to over relatively long durations and experience no more than a 20 percent reduction in survival, growth, and/or reproduction. In order to satisfy the chronic exposure criterion, two conditions must be met:

a. The 30-day average of total ammonia concentration must not exceed the CCC value more than once every 3 years on the average.

b. The highest 4-day average ammonia concentration within the 30-day period must not exceed 2.5 times the CCC.

Note that aquatic species are impacted by very low ammonia concentrations when both pH and water temperatures are high. As either the pH or the water temperature is reduced, aquatic species can withstand exposure to higher ammonia concentrations.

Table H-6. Ammonia (mg/L) Chronic Criteria for the Protection of Salmonids and Fish Early Life Stages.

	Water Temperature in °Celsius													
pH	**14[1/]**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
6.5	6.67	6.46	6.06	5.68	5.33	4.99	4.68	4.39	4.12	3.86	3.62	3.39	3.18	2.98
6.6	6.57	6.36	5.97	5.59	5.25	4.92	4.61	4.32	4.05	3.80	3.56	3.34	3.13	2.94
6.7	6.44	6.25	5.86	5.49	5.15	4.83	4.52	4.24	3.98	3.73	3.50	3.28	3.07	2.88
6.8	6.29	6.10	5.72	5.36	5.03	4.72	4.42	4.14	3.89	3.64	3.42	3.20	3.00	2.82
6.9	6.12	5.93	5.56	5.21	4.89	4.58	4.30	4.03	3.78	3.54	3.32	3.11	2.92	2.74
7.0	5.91	5.73	5.37	5.04	4.72	4.43	4.15	3.89	3.65	3.42	3.21	3.01	2.82	2.64
7.1	5.67	5.49	5.15	4.83	4.53	4.25	3.98	3.73	3.50	3.28	3.08	2.88	2.70	2.53
7.2	5.39	5.22	4.90	4.59	4.31	4.04	3.78	3.55	3.33	3.12	2.92	2.74	2.57	2.41
7.3	5.08	4.92	4.61	4.33	4.06	3.80	3.57	3.34	3.13	2.94	2.76	2.58	2.42	2.27
7.4	4.73	4.59	4.30	4.03	3.78	3.55	3.32	3.12	2.92	2.74	2.57	2.41	2.26	2.12
7.5	4.36	4.23	3.97	3.72	3.49	3.27	3.06	2.87	2.69	2.53	2.37	2.22	2.08	1.95
7.6	3.98	3.85	3.61	3.39	3.18	2.98	2.79	2.62	2.45	2.30	2.16	2.02	1.90	1.78
7.7	3.58	3.47	3.25	3.05	2.86	2.68	2.51	2.36	2.21	2.07	1.94	1.82	1.71	1.60
7.8	3.18	3.09	2.89	2.71	2.54	2.38	2.23	2.10	1.96	1.84	1.73	1.62	1.52	1.42
7.9	2.80	2.71	2.54	2.38	2.24	2.10	1.96	1.84	1.73	1.62	1.52	1.42	1.33	1.25
8.0	2.43	2.36	2.21	2.07	1.94	1.82	1.71	1.60	1.50	1.41	1.32	1.24	1.16	1.09
8.1	2.10	2.03	1.91	1.79	1.68	1.57	1.47	1.38	1.29	1.21	1.14	1.07	1.00	0.94
8.2	1.79	1.74	1.63	1.53	1.43	1.34	1.26	1.18	1.11	1.04	0.97	0.91	0.86	0.80
8.3	1.52	1.48	1.39	1.30	1.22	1.14	1.07	1.00	0.94	0.88	0.83	0.78	0.73	0.68
8.4	1.29	1.25	1.17	1.10	1.03	0.97	0.91	0.85	0.80	0.75	0.70	0.66	0.62	0.58
8.5	1.09	1.06	0.99	0.93	0.87	0.82	0.76	0.72	0.67	0.63	0.59	0.55	0.52	0.49
8.6	0.92	0.89	0.84	0.78	0.73	0.69	0.65	0.61	0.57	0.53	0.50	0.47	0.44	0.41
8.7	0.78	0.75	0.71	0.66	0.62	0.58	0.55	0.51	0.48	0.45	0.42	0.40	0.37	0.35
8.8	0.66	0.64	0.60	0.56	0.53	0.50	0.46	0.44	0.41	0.38	0.36	0.34	0.32	0.30
8.9	0.56	0.55	0.51	0.48	0.45	0.42	0.40	0.37	0.35	0.33	0.31	0.29	0.27	0.25
9.0	0.49	0.47	0.44	0.41	0.39	0.36	0.34	0.32	0.30	0.28	0.26	0.25	0.23	0.22

1/ When temperature is ≤ 14°C, the method of calculating CCC values yields identical results for each pH concentration regardless of temperature.
Source: Corps, 2001. Walla Walla District Hydrology Section. Formula Source: EPA, 1999.

Table H-7 presents the EPA limits for ammonia concentration for acute exposure of aquatic species. Values in the table are the criterion maximum concentration (CMC) values, which define the upper limit of ammonia concentration that aquatic species can be exposed to for short time periods and survive.

Table H-7. Ammonia (mg/L) Acute Criteria for Salmonids Absent or Present.

pH	Salmon are Present	Salmon are Absent
6.5	32.61	48.83
6.6	31.28	46.84
6.7	29.76	44.57
6.8	28.05	42.00
6.9	26.15	39.16
7.0	24.10	36.09
7.1	21.94	32.86
7.2	19.73	29.54
7.3	17.51	26.21
7.4	15.34	22.97
7.5	13.28	19.89
7.6	11.37	17.03
7.7	9.64	14.44
7.8	8.11	12.14
7.9	6.77	10.13
8.0	5.62	8.41
8.1	4.64	6.95
8.2	3.83	5.73
8.3	3.15	4.71
8.4	2.59	3.88
8.5	2.14	3.20
8.6	1.77	2.65
8.7	1.47	2.20
8.8	1.23	1.84
8.9	1.04	1.56
9.0	0.88	1.32

Source: Corps, 2001. Walla Walla District Hydrology Section. Formula Source: EPA, 1999.

Note that the acute criterion is independent of water temperature, but still varies with pH. The limit also varies depending on whether or not salmonids are present.

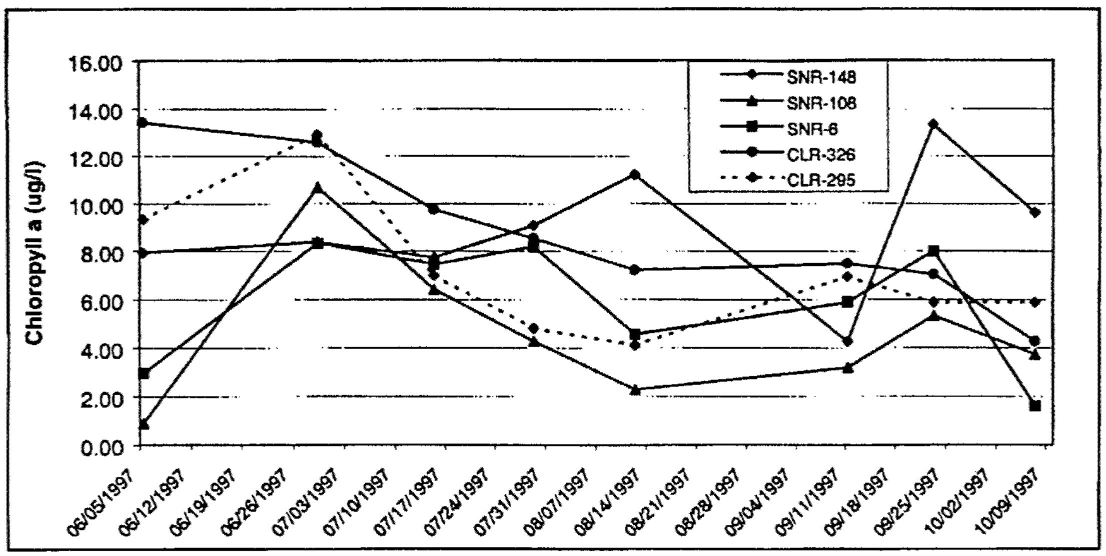
2.5 FOOD BASE

2.5.1 Phytoplankton

Phytoplankton are the most important primary producers in the lower Snake River. The foundation of the food web, they transform light and nutrients into energy for herbivores such as zooplankton which, in turn, support higher trophic levels. Phytoplankton grows best in low velocity waters with warm temperatures and high nutrient availability, particularly phosphorus. Phytoplankton growth is generally limited in stream or riverine systems, which have much

greater flow velocities. In evaluating phytoplankton data, a relative increase in species diversity or richness under similar habitat conditions is often considered a positive indication of improving ambient water quality conditions. In contrast, the dominance of certain robust species, such as some species of blue-green algae, can often be indicative of poor water quality conditions. To evaluate the importance of phytoplankton as a food source, the volume or quantity of algae available for consumption is often the most critical parameter to be considered. For this reason, phytoplankton data is typically expressed in terms of chlorophyll *a* concentration (μg/L) overall biovolume (i.e., μm³/mL), or population densities (i.e., cells/mL) as well as species composition.

Chlorophyll *a* concentrations measured from samples collected at various sites during the growing season between 1994 and 1997 did not display any clear patterns of increasing or decreasing levels. However, data collected during the 1997 growing season were highly variable both temporally and spatially. Although not universal for all stations, the highest seasonal chlorophyll *a* levels were generally observed in June and were associated with an abundance of diatoms. Figure H-6 illustrates the seasonal changes in chlorophyll *a* levels for selected stations within the study area. There appears to be no distinct differences in the chlorophyll *a* levels between the Snake and Columbia River systems. Both the upstream Snake River station at river mile 148 (SNR-148) and the McNary reservoir station at Columbia RM 295 (CLR-295) had similar peak levels in June, which is in contrast to most other parameters.



Source: Corps, 1999

Figure H-6. Chlorophyll *a* for Selected Sampling Stations in 1997.

Previous research suggests that average chlorophyll *a* levels above 5.0 and 14.5 μg/L are indicative of mesotrophic and eutrophic conditions, respectively. Chlorophyll *a* levels will typically range between 3.0 and 11.0 mg/L and 3.0 and 78.0 μg/L for mesotrophic and eutrophic conditions, respectively (Wetzel, 1983). Based on the data from the lower Snake and Columbia Rivers, concentrations of chlorophyll *a* generally are between the criteria for mesotrophic and eutrophic, with an average concentration between 3.8 and 11.4 μg/L, and an upper confidence interval (95 percent) of 18.9 μg/L for the period between 1994 and 1997.

Phytoplankton species assemblages throughout much of the study area were quite similar through 1997, showing a peak in overall density during the last week of June and early July, followed by a decline through mid- to late summer and a secondary peak in autumn. The lower Snake River reach generally had the highest peak densities ranging from 1,303 cells/mL at SNR-108 to 2,842 cells/mL at Station SNR-6. The corresponding biovolumes for these peak densities are 1,133,792 and 1,749,869 μm^3/mL for Stations SNR-108 and SNR-6, respectively. Peak algal densities for the Columbia River stations ranged from 1,516 to 1,832 cells/mL with corresponding biovolumes of 699,846 to 879,791 μm^3/mL at Stations CLR-369 and CLR-295, respectively. The Clearwater River at Station CLW-11 had a relatively low peak density of 749 cells/mL and a biovolume of 321,077 μm^3/mL during the same time period.

There were few differences in the number and types of phytoplankton observed at the impounded pool sites above dams and transitional sites below dams within the lower Snake River system. For most of the study area, diatoms (Bacillariophyta) were typically dominant throughout much of the season, but especially during the peak flow period. At this time, diatoms typically accounted for more than 90 percent phytoplankton biovolumes. The cryptophytes (*Rhodomonas minuta* and *R. m. nannoplanctica*) became dominant or co-dominant (by numerical density) at most sites in the lower 50 miles (80.5 kilometers) of the Snake River during the second half of the season. However, because of their small size, they comprised a relatively small fraction of assemblage biovolume. Phytoplankton blooms (dominated by the genera *Aphanizomenon* and *Anabaena*) do occur in the lower Snake River reservoirs. These blooms are typically brief (lasting only a few weeks) but significant in their total community dominance during that time period and potential subsequent impacts on oxygen concentrations and invertebrate food supply. There have been documented occurrences of surface scum resulting from these taxa. Research has noted much littoral detrital accumulation from senescing planktonic algae blooms during the later summer that deposits on attached benthic algal communities. This senescing planktonic algae likely provides a significant late-summer nutrient input to the attached benthic algal communities, as well as a direct food source for some littoral benthic macroinvertebrates.

2.5.2 Zooplankton

Zooplankton are an important source of food for plankton-eating fish, which in turn are consumed by other fish. Zooplankton assemblages are also expressed in terms of total biomass, population densities, or species composition. Species composition is usually determined first through enumeration and identification of the various organisms in a sample. Total biomass is then calculated through established length/width relationships for each species type. Zooplankton data were analyzed with the same techniques described for phytoplankton. Time series graphs of density estimates were plotted for each location using totals for three major taxonomic groups: rotifers, copepods, and cladocerans. Throughout the season, the highest densities of zooplankton were generally observed in the lower Snake River reservoir sites and in the two McNary reservoir sites (CLR-306 and CLR-295). The transition sites in the upper McNary reservoir (CLR-326) and the Lower Granite reservoir (SNR-118 and SNR-129) generally had lower and somewhat more variable densities. The same was true for the free-flowing Snake (SNR-140 and SNR-148) and Clearwater River sites (CLR-11). However, densities were quite high early in the season at the upstream riverine Snake River site (SNR-148), but dropped sharply thereafter. Densities and taxonomic composition through time in the

free-flowing Hanford Reach (CLR-369) were quite similar to what was found farther upstream in the Priest Rapids reservoir (CLR-397).

Over the entire study area, the 1997 zooplankton assemblage was composed of 30 nominal taxa, distributed fairly equally among members of the phylum Rotifera and two major groups of microcrustacea, Copepoda and Cladocera. This total included at least nine species of cladocerans, four species of copepods, and 11 species of rotifers. At most locations, rotifers were most abundant early in the season, then tapered off in density later in the sampling season. However, the number of different species (i.e., taxa richness) at most locations varied considerably between sampling events. Over the entire season, total zooplankton richness seems to depend mostly on the reach type, with reservoir sites supporting the most taxa and riverine sites supporting the fewest. Reservoir and transition sites usually supported between 7 and 16 individual taxa, while riverine sites on the Snake and Clearwater rivers supported no more than eight taxa at any given time. The Hanford Reach, CLR-369, had the greatest variability with anywhere between 1 and 11 taxa identified depending on the sampling event.
In decreasing order of system-wide abundance, taxa that occurred at a mean density of more than or equal to 0.1 individuals/L (averaged over all sites and times) included the cladoceran *Daphnia retrocurva*, cyclopoid copepods, the copepod *Diacyclops thomasi*, the cladoceran *Bosmina longirostris*, copepod nauplii, and the rotifer *Keratella cochlearis*.

2.6 BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates are an important link in the food web between primary producers and secondary consumers such as bottom feeding fish and large invertebrates, which consume benthic macroinvertebrates. The most recent benthic macroinvertebrate information consists of data collected in 1994 and 1995 from three locations in Lower Granite reservoir on the Snake River. The three locations sampled include the Offield site in the lower portion of Lower Granite reservoir, an artificial shoal-dredge disposal area in mid-reservoir called Centennial Island, and the Silcott Island site (a large island/backwater complex located a few miles downstream of Lewiston-Clarkston within the upper third of the reservoir). Sampling methods involved use of an aerial sampler that enabled a spatial density measurement of the number of organisms per square yard (meter) of bottom area.

Samples were collected at approximately monthly intervals from March 1994 through October 1995. Separate grabs were taken at depths of 3.3, 9.8, and 19.7 yards (3, 9, and 18 m) from each location. A total of 42 nominal taxa of benthic macroinvertebrates were collected in 1994-1995 at the three different locations. Generally, a greater variety of taxa were observed at the shallower depths [3.3 and 9.8 yards (3 and 9 m)]. Some organisms were identified to species, but many taxa were lumped into broad taxonomic categories (e.g., Bivalvia). Oligochaete worms were numerically dominant at all three stations in both years, but were particularly abundant at Silcott and Centennial Islands. Chironomids were second in abundance at all three sites and actually exceeded densities of oligochaetes on a few occasions at the Offield site. These two groups comprised 82 to 97 percent of the total collection from each station. Bivalve mollusks comprised nearly 12 percent of the collection at Offield, but made up less than 2 percent of the collection elsewhere.

3.0 SEDIMENT QUALITY

3.1 REVIEW OF SEDIMENT QUALITY DATA OBTAINED FOR FEASIBILITY STUDY

The purpose of the sediment investigation performed for the Lower Snake River Juvenile Salmon Migration Feasibility Study (Feasibility Study) was to determine the concentration and distribution of potential contaminants residing in these sediments of the four lower Snake River dams. This study was conducted in two phases. The first phase was to collect transects of the particle-size distribution and target specific areas where finer-particle-size materials were predominant. Using that data, the Corps collected representative samples using 8-centimeter-diameter by 2-meter-long (3-inch-diameter by 7-foot-long) Balchek gravity core samplers. A total of 487 grab sediment samples were collected as part of the Phase 1 task of the Lower Snake River Juvenile Salmon Migration Feasibility Study sediment study (CH2M HILL, 1997). Of the 487 grab samples, 356 were sieved to develop particle-size distributions. The remaining 131 samples (or 26.9 percent) were not sieved either because there was no sample recovery or because the sample consisted only of gravel and/or cobble. The average grain size distributions for the sediment samples collected from above Ice Harbor, Lower Monumental, Little Goose, and Lower Granite Locks and Dams are summarized in Table H-8.

Table H-8. Summary of Sieve Test Results for Sediment Samples Collected from the Lower Snake River in 1997

	Average Grain Size (in percent by Weight)			
Sediment Size Wentworth Scale	**IHR**	**LM**	**LGO**	**LGR**
Gravel	2.4	2.8	1.9	0.4
Very Fine Gravel	0.1	0.6	0.7	0.3
Very Coarse Sand	0.1	1	0.7	0.5
Coarse Sand	1.1	1.1	2.8	1.7
Medium Sand	18.3	2.8	10.2	6.9
Fine Sand	18.3	6.7	13.1	17.1
Very Fine Sand	23.3	13.2	16.8	20.1
Silt/Clay	35.8	71.8	53.8	52.4

Notes: IHR - Ice Harbor Reservoir (Lake Sacajawea), 41 samples
LM - Lower Monumental Reservoir (Lake West), 77 samples
LGO - Little Goose Reservoir (Lake Bryan), 127 samples
LGR - Lower Granite Reservoir (Lower Granite Lake), 104 samples
Source: Corps LSRJSMF (Corps 2001)

3.1.1 Chemical Analysis of Sediment Samples

The sediment samples were tested for the following organic compound groups: chlorinated herbicides, dioxins, glyphosate herbicide, organochlorine pesticides, organophosphorus pesticides, semi-volatile compounds, and total petroleum hydrocarbons. A few chlorinated herbicides, organophosphorus pesticides, or semi-volatile organic compounds were detected in

composite top layer sediment samples. In other studies, organic contaminants were detected sporadically.

In 1998, there was no 2,3,7,8-TCDD detected in the Lower Granite sediment sample sites established by Potlatch (CH2M HILL, 1999). Neither the Potlatch nor the Boise Cascade mill was mentioned in EPA's "The Incidence and Severity of Sediment Contamination in the Surface Waters of the United States" (1997).

Dioxin and Furan samples were taken during the 1992 draw down test of the Lower Granite pool. Of the 19 sediment composite samples analyzed for dioxin/furan compounds, five yielded 0.62 parts per trillion (ppt) 2,3,7,8-TCDD and 15.5 ppt 2,3,7,8-TCDF below the Boise Cascade Mill and an average of 0.43 ppt 2,3,7,8-TCDD and 2.72 ppt 2,3,7,8-TCDF below the Potlatch Mill (Pinza et al., 1992).

In the Lewiston-Clarkston Area, the Corps operates a series of pumping plants that discharge water trapped inside the levees to the Snake and Clearwater rivers. In 1994, the Corps conducted sediment and water quality studies to determine the extent of contamination from various non-point sources (particularly storm water runoff). Results from dioxin/furan analysis yielded 0.68 ppt 2,3,7,8-TCDD and 1.34 ppt 2,3,7,8-TCDF in the Corps East Pond. An inlet stream into the east pump pond yielded 4.56 ppt 2,3,7,8-TCDD and 68.6 ppt 2,3,7,8-TCDF (MRI, 1994).

The dioxin and furan tests conducted for the LSRJSMFS included collection of sediment samples downstream of the previous sediment samplings. Only two of the four samples yielded detection for total dioxins at 0.69 and 1 ppt (individual 2,3,7,8-TCDD was undetectable) (CH2M HILL, 1997).

In 1998, prior to the confluence dredging, the Corps initiated a sediment study where nine samples were taken in the confluence area near RM 139. Only two of the nine samples yielded a result with 1.3 and 1.7 ppt 2,3,7,8-TCDF and no detect for 2,3,7,8-TCDD (HDR, 1998).

Also in 1998, CH2M HILL, under contract to Potlatch Corporation, conducted dioxin tests in the Lower Granite pool and Clearwater arm of the pool. Seven sites were selected and individual subsets were combined into composite sample for analysis. A Ponar sampler was used to sample the top 7.5 inches of the sediments. Results from sediments at all of the in river sites sampled consisted of no detects and below detection limits for 2,3,7,8-TCDD and 2,3,7,8-TCDF. The only sample that contained a detectable level of contamination was the Corps East Pond (CH2M HILL, 1999). The concentrations of 2,3,7,8-TCDD and 2,3,7,8-TCDF were very low-2.8 ppt and 3.4 ppt, respectively. The East Pond is directly adjacent to the Potlatch mill, but receives storm runoff from multiple sources. Potlatch again repeated the study in 1999 and discovered the only detection was for 2,3,7,8-TCDF in the amount of 23 ppt, again in the East Pond sampling area (CH2M-HILL, 2000).

Glyphosate was detected in 36 percent of the samples, and AMPA was detected in 16 percent of the samples tested. The concentration of glyphosate ranged from non-detected to a maximum of 68.9 ppb (parts per billion) with an arithmetic mean of 12.52 ppb. The concentration of AMPA

ranged from non-detected to a maximum of 29.3 ppb with an arithmetic mean of 7.48 ppb (Anatek, 1997). See Table H-9.

Table H-9. Summary of Average Glyphosate AMPA Concentrations (µg/L) for Sediment Samples Collected during 1997 in the Lower Snake River

	Ice Harbor	Little Goose	Lower Monumental	Lower Granite	Average
Elutriate					
AMPA	ND	ND	ND	ND	ND
Glyphosate	0.58	0.69	ND	ND	0.57
Sediment					
AMPA	8.08	7.58	6.07	8.28	7.48
Glyphosate	16.80	10.42	10.60	14.85	12.52

Note: ND = Not detected; ½ the detection level is used when concentrations are less than detection level.
Source: Anatek (1997).

Several organochlorine pesticides were detected in the sediment samples collected from the lower Snake River. The organochlorine pesticide compounds detected (and their frequency of detection) included: 4,4-DDD (11); 4,4-DDE (43); 4,4-DDT (5); aldrin (3); dieldrin (4); endrin (1); heptachlor (1); and lindane (3) (Anatek 1997, see Table H-10). The three principal organochlorine pesticide compounds detected in the sediments are related, with DDT being the parent compound and DDD-DDE being daughter products generated by the transformation of DDT in the environment.

Table H-10. Summary of Average Concentrations (ppb) of Organochlorine Pesticides and TPH in Sediments Collected during 1997 in the Lower Snake River

	Ice Harbor	Little Goose	Lower Granite	Lower Monumental	Average
Sediment					
4,4-DDD	ND	1.95	3.06	1.58	2.07
4,4-DDE	2.68	4.91	6.48	4.22	4.89
4,4-DDT	ND	1.64	1.72	1.56	1.62
Aldrin	0.75	0.84	0.87	0.82	0.83
Dieldrin	ND	1.74	ND	1.80	1.68
Endrin	ND	ND	ND	1.75	1.58
Lindane	ND	0.91	ND	0.90	0.85
TPH	67.63	45.86	58.25	49.15	55.41

Note: ND = Not detected; average uses ½ of detection when concentrations are less than detection level.
Source: Developed by Normandeau

The pesticides aldrin, dieldrin, endrin, heptachlor, and lindane were all detected in five or fewer of the 1994 dredged material sediment evaluation samples. The concentration of aldrin ranged from nondetect to 3.5 ppb, dieldrin from nondetect to 8 ppb, endrin from nondetect to 9.4 ppb, heptachlor from nondetect to 4.9 ppb, and lindane from nondetect to 5.5 ppb. The maximum concentrations of aldrin, dieldrin, heptachlor, and lindane in the Snake River sediment are lower than their screening level concentration of 10 ppb. No screening level has been established for endrin in the DMEF (Corps, 1998).

Since the early 1980s, the Walla Walla District monitored sediment prior to dredge operations for a suite of organic compounds. Organochlorine pesticides were at the top of the list of constituents for which to test. In the sediment analysis studies for 1984 and 1985 for interim dredging (Corps, 1986; 1987), the Corps sampled sediments between the Port of Lewiston and the confluence of the Snake and Clearwater River. In seven sample sites 4,4-DDD ranged from less than 0.3 to 3 ppb and 4,4-DDE ranged from less than 0.3 to 4.8 ppb. In 1988, during dredging in the upper end of the reservoir behind Lower Granite Lock and Dam, the Walla Walla District found 4,4-DDT (6 ppb) at a site in the Clearwater Snake River Confluence and at 7 and 21 ppb at two areas in an in-water disposal site at Snake River RM 120 (Corps, 1987).

The Walla Walla District-sponsored study (Sediment Sampling of Proposed Dredge Sites in the Confluence of the Snake and Clearwater Rivers, Pinza et al., [1992]) tested 19 sites for chlorinated pesticides at port areas on the lower Snake and Columbia rivers. The compound 4,4-DDT ranged from 0.6 to 1.8 ppb, which was below laboratory detection limits. The DDT metabolite 4,4-DDD ranged from 0.4 to 4.8 ppb and DDT metabolite 4,4-DDE ranged from 0.6 to 16 ppb. Other organochlorine pesticides were found at below laboratory detection limits of 0.2 ppb.

The Walla Walla District 1996 Sediment Study for the Confluence Dredging of the lower Snake and Clearwater Rivers for the Port of Lewiston and Port of Clarkston (Corps, 1999) reported low levels of DDT. The compound 4,4-DDT at two sites in the Confluence ranged from 3 to 6 ppb; 4,4-DDD in five sites at the Confluence ranged from 2 to 4 ppb; 4,4-DDE in five sites at the Confluence ranged from 3 to 11 ppb.

In the sedimentation study for the Feasibility Study, total petroleum hydrocarbons (TPHs) were analyzed in all four lower Snake River reservoirs. The concentration of TPH ranged from nondetect to 256 ppm (LM 1-2) with an arithmetic mean of 55.41 ppm (Anatek 1997). Along the lower Snake River, the average concentration of TPH generally increases in the downstream direction with the highest average reach concentration (62.13 ppm) found in Lake Sacajawea. No screening levels were established for TPH under the Portland District's Dredged Material Evaluation Framework (Corps, 1998).

Crecelius and Gurtisen (1985) reported oil and grease concentrations from sediment sites near Clarkston, Washington, on the Snake River ranging from 62 to 222 ppm. The Walla Walla District reported oil and grease in the sediments ranging from 38 to 1,096 ppm. Only two of these samples were greater than 500 ppm and these were both detected at disposal site on Lower Granite pool at Snake River RM 120. Pinza et al. (1992) reported oil and grease concentrations

ranging from 12.62 to 208.70 ppm for mid Columbia and Snake River sites. Total petroleum hydrocarbons ranged from 12.20 to 96.27 ppm.

The first recorded sample and analysis effort for polynuclear aromatic hydrocarbons (PAHs) was conducted in the Port of Lewiston area in 1985. Crecelius and Gurtisen (1985) did the first serious study of PAHs in the Snake River system prior to a confluence dredging analysis. In their analysis of sediment core samples from the Port of Clarkston area, the total PAH concentration ranged from 77 ppb to 865 ppb. Using the Puget Sound apparent no-effect (AET) guideline, low-weight PAH ranged from 16 to 58 ppb compared to the limit of 5,200 ppb. High-weight PAH ranged from 0 to 111 ppb compared to the limit of 12,000 ppb. Crecelius and Cotter (1986) revisited the Lewiston area locations and found only trace amounts of low-molecular-weight PAH compounds. High-molecular-weight PAH compounds ranged from 54 ppb to 818 ppb. During this study fluoranthene was the predominant detected PAH. This compound is usually associated with other similar-weight compounds; it was unusual to detect flouranthene with little or none of the other high-molecular-weight PAHs.

The Clearwater and Snake River confluence sediments were again looked at prior to the 1987 dredging. During this investigation, no low-molecular-weight PAH compounds were detected (Corps, 1987). Of the PAH compounds detected those present were predominantly pyrene and perylene. Perylene is commonly found in sediments containing substantial amounts of decaying material and was not an EPA priority pollutant in 1987. In this study, flouranthene was present but in small amounts relative to pyrene, which was the most commonly found PAH. The highest concentration of low-molecular PAH was 1,544 ppb in the disposal area.

Pinza et al. (1992) conducted the next significant dredge material study again in the Snake and Clearwater confluence area. This study analyzed the 10 most common PAH compounds expected to be found in this area based on industrial and regional land use practices. Composite samples were taken from the proposed disposal site, Port of Wilma, Port of Clarkston SRP 24 and 25, Port of Clarkston SRP 26 and 27, Port of Lewiston 28 and 29, Port of Lewiston SRP 30-32, Port of Lewiston SRP 33 and 34; and the Port of Almota. The calculated results for low-molecular-weight PAHs derived from the reported individual species were: 12.4 ppb, less than detection limit, 13.7 ppb, 10.9 ppb, less than detection limit, 15.3 ppb, less than detection limit, and less than detection limit, respectively. The calculated results for the high-molecular-weight PAHs were: 34.4 ppb, less than detection limit, 46 ppb, 15.8 ppb, less than detection limit, 25.7 ppb, 211 ppb, and less than detection limit, respectively. This study suggested PAHs were relatively low in environmental concentration and substantially less than found in the previous studies.

The best data available in 1998 and 1999 are the Potlatch Corporation reports (CH2M HILL, 1999: and 2000). CH2M HILL (1999) reported that the Lower Granite pool and Clearwater arm samples generally showed low-molecular-weight PAHs to be less than 10 ppb and high-molecular-weight PAHs to be less than 50 ppb. The exception was the Corps East Pond. The East Pond results reported 300 ppb low-molecular-weight PAHs and 492 ppb high-molecular-weight PAHs. This is borderline for the Puget Sound protocols for low-molecular-weight compounds. It is noteworthy that the East Pond sample detected every PAH compound that was analyzed. The 1999 sampling (CH2M HILL, 2000) reported slightly lower total concentrations

of PAH compound than the previous year. The East Pond still contained all species of PAHs tested, with 157 ppb and 446 ppb levels for low- and high-molecular-weight compounds, respectively.

The concentrations and distributions of PAH compounds are adequately documented in the Lower Granite pool. Almost no data exist on PAH distributions and concentrations in the Little Goose, Lower Monumental, Ice Harbor and McNary reservoirs.

In 1997, each of the 94 LSRJSMFS sediment samples was analyzed for a suite of 18 metals (inorganic). The metals analyzed included: arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, vanadium, and zinc. Of the 18 metals analyzed only cadmium, mercury, silver, and strontium were not detected in all 94 samples. Cadmium was detected in only two samples, mercury in 37 samples, silver was not detected in any of the samples, and strontium was detected in only four samples (Anatek, 1997).

The metal consistently found in the highest concentrations was manganese. This metal is commonly detected in river sediments due to its high relative abundance in the natural environment.

Concentrations of manganese in individual sediment samples collected from the lower Snake River during this investigation ranged from 250 ppm to 1,044 ppm with an average concentration of 430 ppm (Anatek 1997). In comparison, the concentration of manganese in sediment samples collected upstream of the study area by the USGS (Clark and Maret, 1998) ranged from 370 ppm to 1,000 ppm with an average concentration of 564 ppm.

No consistent trends in sediment metal concentrations were observed going downstream from Lower Granite Lake to Lake Sacajawea (Table H-11). When compared with the results obtained by the USGS (Clark and Maret, 1998) in their investigation of the Snake River upstream of the study area several trends do become apparent. In the USGS investigation, bed sediments were collected and analyzed for a broad range of trace elements. Upstream concentrations of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc (USGS) were lower than downstream concentrations (this investigation).

Concentration values for metals in sediments are also available for the Lower Columbia River drainage basin (Corps, 2002). Of the reported values for the metals arsenic, cadmium, copper, lead, mercury, nickel, silver, and zinc in these previous investigations, only the concentrations of arsenic, manganese, and lead were found to be slightly higher for the samples collected from the lower Snake River during this investigation.

Table H-11. Summary of Mean Metal Concentrations for Sediment Samples Collected (1997) in the Lower Snake River for the LSRJSMFS

Metal (mg/kg)	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Arsenic	6.3	3.9	6	5.2
Barium	170.6	157.2	192.7	180.8
Beryllium	0.6	0.6	0.7	0.7
Cadmium	ND	ND	ND	0.1
Chromium	20.2	17.7	22.4	23
Cobalt	10.9	8.2	11.1	12
Copper	20.8	16.8	24.8	29.8
Lead	10.5	8.8	12.6	12.9
Manganese	510.1	384.6	475.2	408.9
Mercury	0.1	0.1	0.1	0.1
Molybdenum	0.3	0.2	0.2	0.3
Nickel	14.2	12.4	15.6	16.6
Selenium	1.6	1.4	1.3	1.5
Silver	ND	ND	ND	ND
Strontium	0.1	0.1	ND	0.1
Thallium	0.2	0.2	0.2	0.2
Vanadium	45.1	37.9	47.2	60.9
Zinc	52.5	45	57.3	61.4

Notes: All concentrations in mg/kg (ppm)
Ice Harbor Lock and Dam-Lake Sacajawea
Lower Monumental Lock and Dam-Lake West
Little Goose Lock and Dam-Lake Bryan
Lower Granite Lock and Dam-Lower Granite Lake
Source: Developed by Normandeau

Crecelius et al. (1985) conducted a comprehensive evaluation of material from proposed dredging locations prior to the confluence dredging of 1986. Metals concentrations of copper, lead, zinc, and cadmium were very similar to levels found during the sediment examination for the Feasibility Study when compared to the geometric mean. The outliers were mercury and chromium. Mercury levels were lower and ranged from 0.015 to 0.049 milligrams per kilograms (mg/kg). Chromium was somewhat higher and ranged from 26 to 43 ppm. The highest readings compared to the mean background levels (San Juan, 1994; Table H-12) resulted in chromium at 3.4 times higher and mercury at 7 times higher than the eastern Washington median value. The highest mercury level in this study was twice as high as the maximum eastern Washington State natural background levels (San Juan, 1994).

Table H-12. Comparison of Metal Concentrations in Eastern Washington (Minimum, Mean, and Maximum) to the State Wide Mean
The table was adapted using data from the San Juan (1994) report.

	Metals (ppm)			
	Median	**Minimum**	**Maximum**	**Statewide mean**
Aluminum	14,800.000	6,140.000	29,000.000	19,575.000
Arsenic	2.530	0.500	7.190	2.920
Beryllium	0.305	0.230	0.875	0.670
Cadmium	N/A	N/A	N/A	0.490
Chromium	12.600	5.000	71.300	18.420
Copper	14.700	9.100	53.000	17.070
Iron	21,300.000	10,400.000	30,000.000	22,033.000
Lead	6.400	4.200	11.700	7.900
Manganese	345.000	223.000	652.000	509.580
Mercury	0.007	0.004	0.025	0.020
Nickel	11.700	6.400	34.100	16.430
Selenium	N/A	N/A	N/A	0.525
Silver	N/A	N/A	N/A	0.037
Tin	N/A	N/A	N/A	4.000
Zinc	41.00	26.300	82.300	51.120

Source: Developed by the Corps

The Walla Walla District 1988 Interim Flood Control Dredging (Corps, 1986) study reported concentrations of sediment metals as follows: arsenic 2.6 to 12.6 ppm, copper 17 to 48 ppm, lead 13 to 27 ppm, mercury 0.018 to 0.186 ppm, and zinc 77 to 138 ppm. Cadmium ranged from 0.075 to 1.02 ppm, which is below Puget Sound Screening level of 5.1 ppm. Maximum metal concentrations from this study compared to mean background levels (San Juan, 1994) were: 3.3 times higher for zinc; 26.5 times higher for mercury; 5.6 times higher for copper; 16 times higher for arsenic; and 4.2 times higher for lead.

The 1992 sediment sampling of the dredge sites on the Snake and Clearwater Rivers (Pinza et al., 1992) reported concentrations as follows: arsenic from 1.11 to 9.46 ppm; cadmium from 0.2 to 1.6 ppm; chromium from 6.6 to 23.4 ppm; copper from 6.9 to 38.8 ppm; lead from 2.5 to 20.8 ppm and mercury from 0.06 to 0.20 ppm. Concentrations of zinc ranged from 26 to 78.7 ppm with the exception of one site that reported a concentration of 277 ppm.

For the 1996/1997 Confluence Dredging in the lower Snake and Clearwater rivers, sediments were sampled and tested for Resource Conservation and Recovery Act (RCRA) metals (Corps, 2002). In this study the sediment concentrations ranged as follows: aluminum 12,200 to 20,300 ppm; arsenic 1.25 to 4.36 ppm; barium 135 to 234 ppm; beryllium 0.5 to 0.71 ppm; chromium 12.2 to 18.2 ppm; cobalt 9.97 to 13.4 ppm; copper 17.3 to 34.9 ppm; lead 6.79 to 10.9 ppm; manganese 259 to 580 ppm; molybdenum 0.29 to 1.35 ppm; nickel 10.3 to 13.5 ppm; selenium 1.29 to 2.17 ppm; thallium 0.15 to 0.19 ppm; vanadium 52.1 to 68.7 ppm; and zinc 38.4 to 69.8 ppm. The aluminum detected in this study was above the mean background levels (San Juan, 1994) in a significant number of the samples. In this study, comparison of the highest

concentrations to the mean background level for eastern Washington were as follows: copper was about twice as high, arsenic was about twice as high, lead was one and a half times higher, but mercury was not detected in any of these samples.

In their reported values for the metals arsenic, cadmium, copper, lead, mercury, nickel, silver, and zinc, only the concentrations of arsenic and lead were found to be slightly higher for the samples collected from the lower Snake River during this investigation. The authors suggested that the major source of metals except arsenic and lead is from the lower Snake River basin.

Sediments were tested in the Lower Granite pool and the Clearwater River in depositional areas upstream and downstream from RM 139. Sediment metal concentrations for both years ranged from: arsenic 1.5 to 13 ppm, cadmium 0.08 to 0.56 ppm, chromium 8.7 to 39 ppm, copper 13 to 55 ppm, lead 4.2 to 34 ppm, nicke19 to 18 ppm, selenium 1 to 2 ppm, and zinc 32 to 249 ppm. In the 1999 report, aluminum ranged from a low of 6,623 ppm to a high of 29,367 ppm. The highest concentration of aluminum was found in the Corps East Pond. The level in the East Pond was about twice the background levels (San Juan, 1994). Lead and chromium were also found above background levels, with the highest number found in the East Pond. The highest copper detection is slightly higher than the highest reading reported in the eastern Washington background samples. In all of the samples from the Potlatch 1999 study, mercury was a nondetected constituent.

The Walla Walla District June 2000 sediment study in the lower Snake and Clearwater rivers tested for metals in 32 sample sites. Results for this study were as follows: antimony all below detection limits; aluminum 232 to 7,885 ppm; barium 2.2 to 108 ppm; beryllium all nondetects; calcium 12.77 to 37.87 ppm; cadmium 0.122 to 1.058 ppm; chromium 1.20 to 9.13 ppm; cobalt 1.099 to 9.573 ppm; copper 2.22 to 44.33 ppm; iron 1.242 to 15,529 ppm; magnesium 9.123 to 405 ppm; manganese 10.97 to 4,009 ppm; molybdenum all nondetects; nickel 1.921 to 9.478 ppm; potassium 6.529 to 2,023 ppm; sodium 5.623 to 253 ppm; vanadium 1.292 to 65.22 ppm; zinc 1.090 to 41.56 ppm; mercury all nondetects; and lead 1.109 to 8.353 ppm. In these samples, chromium and aluminum were detected in significantly lower quantities than in previous studies. These parameters were also well below the expected average background levels. On the other hand, manganese was detected at chronic levels with the highest sample at 11 times more than background levels (San Juan, 1994). Cadmium was twice as high as the state median background level. The maximum copper concentration was two and a half times higher than the eastern Washington background. There are no published state background levels for vanadium. But there is a median datum published for the Spokane River basin, and maximum lower Snake River vanadium is more than twice the median in the Spokane River basin. Copper was also elevated above background levels.

Studies of metals conducted in the 1980s contained significant levels of metals-well above the 1994 background levels. For the most part, metals detected in the current studies, the 1997 Feasibility Study, and current evaluations agreed with each other and were within the range of the expected background levels. There were some notable exceptions and these will be discussed further.

The most notable of these differences is manganese. Manganese concentrations appear to be higher in Snake River sediments than in Clearwater River sediments. Manganese concentrations were highly variable but each successive year of testing yielded a higher maximum concentration. The high manganese concentrations occurred in results from several laboratories, suggesting that a procedural error is unlikely. Some analyses were by atomic absorption spectrometry while others were conducted by inductively coupled plasma mass spectrometry, suggesting a method error was unlikely. At this time there is no explanation for this occurrence. Fractional isotope analysis could provide clues by determining what species of manganese salts and proportion to geologic material is present.

Lead and arsenic appear in quantities above background level (San Juan, 1994) in previous studies. Currently some of the highest levels are present in the Corps East Pond in Lewiston. Lead and arsenic were also used as paint pigments around the turn of the 20th century (Scott, 1887). Lead carbonate was also used as the primary white paint pigment and surface primer until the EPA banned it in 1978 (U.S. Department of Housing and Urban Development, 1990). Sparse population in this region suggests that this source, like tetraethyl lead (Nriagy, 1990), would not be sufficient to contribute greatly to the totals found in sediments.

Since there are few industrial sources of pollution in the area, the source most likely responsible for above background levels for lead and arsenic is past agricultural practices in areas historically containing orchards. The Otis Orchards suburb of Lewiston, Idaho, was once teeming with orchard-grown crops. Old pre-impoundment USGS 7.5-minute quad maps also show orchards where there are now reservoir waters.

For the Lower Snake River Feasibility Sediment Study 84 of the sediment samples were also analyzed for a number of chemical parameters, designated as the nutrient group (although not all of the parameters are true nutrients). The sediments were analyzed for: ammonia, total Kjeldahl nitrogen (TKN), nitrogen as nitrate/nitrite, total organic nitrogen, total organic matter, pH, phosphorus bicarbonate, and sulfate. The mean reach concentrations for each of the nutrient group parameters are summarized in Table H-13.

Table H-13. Summary of Mean Nutrient Concentrations for Sediment Samples Collected in the Lower Snake River

Parameter	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Ammonia	81.3	59.6	64.3	75.7
Total Kjeldahl Nitrogen	1,317.1	1,146.1	1,344.1	1,746.5
Nitrate/Nitrite	0.7	0.6	0.7	1.4
Total Organic Nitrogen	1,235.7	1,086.7	1,280	1,671.3
Total Organic Matter (percent)	2.5	2.2	3.3	5.2
Phosphorus Bicarbonate	37.7	38.2	35	34.1
Sulfate	7.7	8.4	10.5	17.9
Sediment (soil) pH (standard units)	6.9	6.9	7.1	6.8

Notes: All results in mg/kg otherwise noted
Ice Harbor Lock and Dam - Lake Sacajawea
Lower Monumental Lock and Dam - Lake West
Little Goose Lock and Dam - Lake Bryan
Lower Granite Lock and Dam - Lower Granite Lake
Source: Corps 1999

3.1.2 Chemical Analysis of Elutriates

The purpose of the 1997 elutriate tests was to evaluate potential impacts on surface water quality from the re-suspension of channel sediment. The elutriate tests were used to determine which inorganic or organic constituents would preferentially partition by dissolution into the water and to determine their resulting potential aqueous concentration during drawdown. The elutriate concentrations (maximum values) were then compared with applicable surface water quality standards. The results of the laboratory analyses for the ambient pH elutriate, which are summarized in Tables H-14 and H-15, are presented in Anatek (1997). Results include the number of samples analyzed, the number of samples above detection limits, the minimum value and maximum value detected, the arithmetic and geometric mean, and the standard deviation for each parameter analyzed.

Table H-14. Summary of Mean Metal Concentrations for Ambient pH Elutriate Samples Collected in the Lower Snake River Project

Metal (μg/L)	Ice Harbor	Lower Monumental	Little Goose	Lower Granite
Arsenic	3.9	2.6	2.2	1.8
Barium	243.6	197.5	140.9	83.3
Beryllium	ND	ND	ND	ND
Cadmium	ND	ND	0.1	ND
Chromium	0.6	0.8	0.4	0.6
Cobalt	0.5	1.2	0.4	0.5
Copper	2.9	3.2	3.2	4
Lead	ND	0.1	0.1	0.1
Manganese	861.5	1,432.1	799.9	504.4
Mercury	ND	0.1	0.1	0.1
Molybdenum	3	3.5	3.8	2.2
Nickel	2.8	4.1	0.7	0.9
Selenium	2.3	1.2	0.3	0.3
Silver	ND	ND	ND	ND
Strontium	0.4	0.3	0.3	0.2
Thallium	ND	ND	ND	ND
Vanadium	2.1	1.2	1.8	1.5
Zinc	37.7	17.8	16.9	12.9

Notes: ND=not detected
Ice Harbor Lock and Dam-Lake Sacajawea
Lower Monumental Lock and Dam-Lake West
Little Goose Lock and Dam-Lake Bryan
Lower Granite Lock and Dam-Lower Granite Lake
Source: Corps 2000

Table H-15. Summary of Mean Nutrient Concentrations for Ambient pH Elutriate Samples Collected during Phase 2 (1997) in the Lower Snake River

Parameter (milligrams per liter)	**Ice Harbor**	**Lower Monumental**	**Little Goose**	**Lower Granite**
Ammonia	3.6	2.5	2.6	3.6
Total Kjeldahl Nitrogen (TKN)	8.8	5.7	4.1	6.2
Nitrate/Nitrite	0.2	0.2	0.3	0.4
Phosphate	0.1	0.1	0.1	0.1
Sulfate	19.6	17.9	26.9	29.7

Note: Ice Harbor Lock and Dam - Lake Sacajawea
Lower Monumental Dam - Lake West
Little Goose Lock and Dam - Lake Bryan
Lower Granite Lock and Dam - Lower Granite Lake
Source: Corps 2000

The ambient pH elutriates were tested for the presence of organophosphorus pesticides, which as a group consist of 25 different organic compounds. The only organophosphorus pesticide detected was ethyl parathion, in one sample (Little Goose 8-4), at a concentration of 1.0 ppb (μg/L). Although identified in the one elutriate sample, ethyl parathion was not detected in any of the sediment samples. Parathion is a regulated substance in fresh waters in the states of Oregon and Washington with a maximum allowable concentration of 0.013 ppb (chronic).

No organochlorine pesticides were detected in any of the ambient pH elutriate samples. The organochlorine pesticides DDT (and its metabolites), aldrin, dieldrin, endrin, heptachlor and lindane had been detected in several of the sediment samples tested. The results of the elutriate tests suggest that although these compounds are present in the sediments they do not readily partition into water.

Glyphosate was detected in only 2 of the 94 ambient pH elutriate samples, while AMPA was not detected. Glyphosate was detected at a concentration of 0.69 μg/L in a sample collected from Lake Bryan and at a concentration of 0.58 μg/L in a sample collected from Lake Sacajawea. In comparison, the maximum contaminant level established for glyphosate by the EPA in drinking water is 700 μg/L, well above the concentrations detected in the two elutriate analyses.

Each of the 94 ambient pH elutriates were tested for the same suite of metals that were analyzed on their corresponding sediments. The results of the individual samples are summarized in a table included in Corps (2002). For the 18 metals analyzed only beryllium, silver, and thallium were not detected in the elutriate samples. Of these metals only silver was not detected in the original sediment samples.

The mean metal concentrations for the ambient pH elutriates are summarized by river reach in Table H-14. The predominant metals detected include barium and manganese. The average concentration of barium, by river reach, in the ambient pH elutriates increases from 83.3 ppb for

the samples collected from Lower Granite Lake to 243.6 ppb for the sediment samples collected from Lake Sacajawea. Although a corresponding trend in the concentration of barium in the sediment samples was not observed, it was one of the predominant metals detected. Its relatively high concentration in the ambient pH elutriates is most likely the result of its concentration in the sediments and its relatively high solubility in water (Hem, 1989).

The predominant metal identified in the ambient pH elutriates was manganese. The average concentration of manganese, by river reach, in the ambient pH elutriates ranged from 504 ppb for the samples collected from Lower Granite Lake to 1,432 ppb for the samples collected from Lake West. In general, the trend in manganese concentrations in the ambient pH elutriate samples increases with distance downstream. As observed with barium, there does not appear to be a clear relationship between the concentration of manganese in the sediment samples and in the ambient pH elutriates.

The maximum metal concentrations detected in the ambient pH elutriates (Anatek, 1997) were also compared with the recommended surface water quality standards of the State of Oregon Department of Ecology, the United Nations (agricultural water quality goals), EPA, and Ecology to identify any chemicals of concern. The maximum concentration of four metals: arsenic, copper, manganese, and mercury could be in excess of applicable water quality standards when re-suspended during dredge operations.

The ambient pH elutriate samples were also analyzed for the following nutrients: ammonia, nitrate/nitrite, phosphate, sulfate, and Total Kjeldahl Nitrogen (TKN) (Cascade Analytical, 1997). The mean concentration of each of these nutrients for the four reaches along the lower Snake River are summarized in Table H-15

Concentrations of ammonia in sediment elutriate and in ambient river are summarized in Figure H-7. These data indicate that erosion and suspension of sediments can substantially elevate ammonia in the water column above ambient levels. Although elevated ammonia levels are expected to be transient, they nevertheless could affect aquatic life.

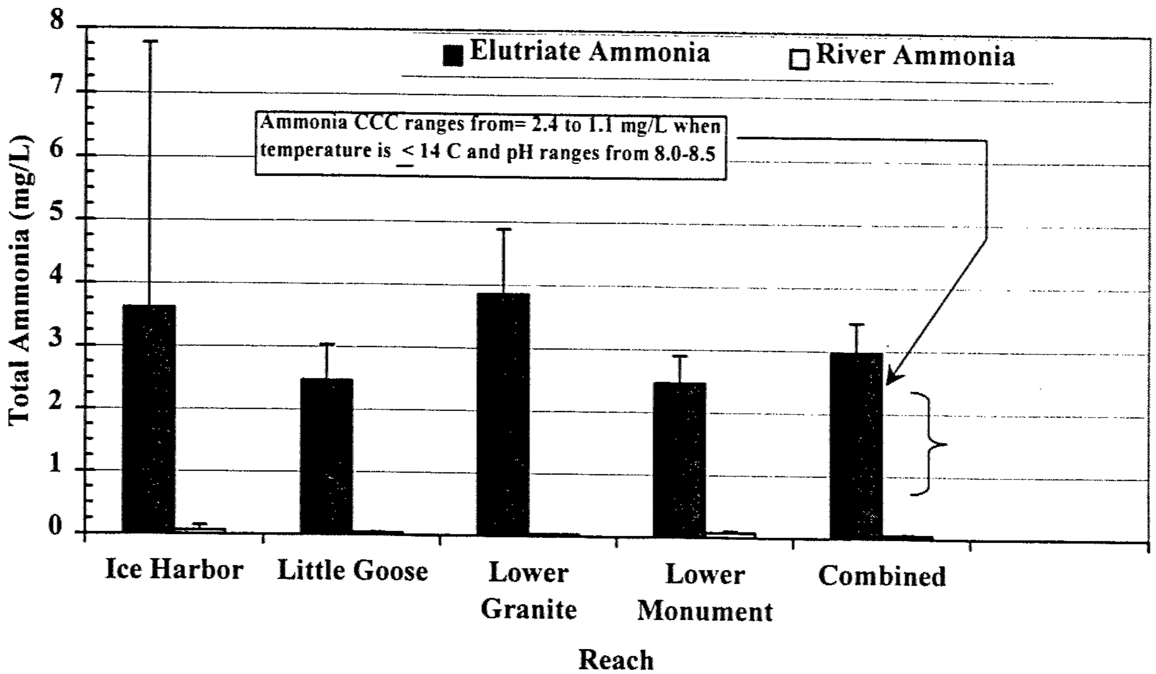


Figure H-7. Mean Concentrations and 95 Percent Confidence Limits of In-river Water and In-sediment Elutriate at Ambient pH.

3.2 SEDIMENT SAMPLING IN THE PROPOSED AND POSSIBLE FUTURE DREDGING SITES

The Dredged Material Evaluation Framework: Lower Columbia River Management Area (Corps, 1998) was used as the regulatory guidance for sediment quality evaluations in this Appendix. When Walla Walla District develops an evaluation framework specifically for the Lower Snake River Project reach and the McNary Project reach of the Columbia River, it will provide the regulatory guidance for future sediment quality evaluations within District boundaries. In June of 2000, water quality/sediment samples were collected at sites proposed for dredging in the winter of 2002 and 2003 in the Lower Snake River Reservoirs. The following tabulation outlines the number of sampling stations where data was collected.

Reservoir Project	Number of Stations
Lower Granite	55
Little Goose	6
Lower Monumental	1
Ice Harbor	5

The number of compounds tested at each site typically ranged from about 29 to over 80 depending on the specific sampling site. The specific sample site and compounds tested for were based on locations and data previously sampled under previous pre-dredging analyses. Pre-

dredging data has been collected since 1985. The following information summarizes the data that was collected in June of 2000.

The semi-volatile organic compounds, poly-nuclear aromatic hydrocarbons analyzed using EPA method 8270C were as follows: (none of these compounds were detected at levels that would require bioassay testing under the Lower Columbia Framework criteria.

Table H-16 List of Parameters Analyzed with Method EPA 8270C

1,2-Dichlorobenzene *	1,2,4,5-Tetrachlorobenzene *	1,3-Dichlorobenzene *
1,4-Dichlorobenzene *	1-Methylnapthalene *	2,4-Dichlorophenol *
2,4-Dimethylphenol *	2,4,Dinitrophenol	2,4-Dinotrotoluene *
2,4,6-Trichlorophenol *	Dibenz (a, h) anthracene *	2-Chloronaphthalene *
2-Chlorophenol *	2-Methyl-4,6-dinitrophenol *	2-Methylnapthalene *
Di-n-octyl phthalate *	2-Nitrophenol *	3,3'-Dichlorobenzidine *
4-Bromophenyl phenyl ether *	4-Chloro-3-methylphenol *	4-Chlorophenyl phenyl ether *
4-Nitrophenol *	Hexachlorobenzene *	Hexachlorobutadiene *
Hexachloroethane *	Acenaphthene	Acenaphthylene
Anthracene	Bis (2-chloroethyl) ether *	Bis (2-chloroisopropyl) ether *
Bis (2-ethylhexyl) phthalate *	Benzo (a) anthracene	Benzo (a) pyrene *
Benzo (b) floranthene	Bis (2-chloroxy) methane*	Benzo (g, h, I) perylene
Benzo (k) flouranthene *	Butyl benzyl phthalate *	Chrysene
Diethyl phthalate *	Di-n-butyl phthalate	Dimethyl phthalate *
Fluoranthene	Flourene	Ideno (1,2,3-c, d) pyrene
Isophorone *	Napthalene	Nitrobenzene *
Pentachlorophenol	Phenanthrene	Phenol *
Pyrene	1,2,4-Trichlorobenzene *	Pentachloroanisole

* Below Detection Limits

The semi-volatile and poly nuclear aromatic hydrocarbon compounds below detection limits were; 1,2-Dichlorobenzene; 1,2,4,5-Tetrachlorobenzene; 1,2,4-Trichlorobenzene; 1,4-Dichlorobenzene; 1-Methylnapthalene; 2,4-Dichlorophenol; 2,4-Dimethylphenol; 2,4-Dinotrotoluene; 2,4,6-Trichlorophenol; Dibenz (a, h) anthracene; 2-Chloronaphthalene; 2-Methyl-4, 6-dinitrophenol; 2-Methylnapthalene; 2-Chlorophenol; Di-n-octyl phthalate; 2-Nitrophenol; 3,3'-Dichlorobenzidine; 4-Bromophenyl phenyl ether; 4-Chloro-3-methylphenol; 4-Chlorophenyl phenyl ether; 4-Nitrophenol; Hexachlorobenzene; Hexachlorobutadiene; Hexachloroethane; Bis (2-chloroethyl) ether; Bis (2-chloroisopropyl) ether; Bis (2-chloroxy) methane; Benzo (k) flouranthene; Butyl benzyl phthalate; Diethyl phthalate; Dimethyl phthalate; Isophorone; Nitrobenzene; Phenol; Benzo (a) pyrene; 1,3-Dichlorobenzene; Bis (2chloroisopropyl) ether; 2,4 Dichlorophenol; and Bis (2-ethylhexyl) phthalate.

Acenaphthene was detected in Federal Navigation Channel but not in the Green Belt Boat Basin, Hell's Canyon Resort Marina, and the Port of Lewiston. The channel samples where detections were quantified all reported 74.6 ppb. About 1/3 of the samples rendered a measurable detection. With a screening level of 500 ppb no biological effects were anticipated.

Acenapthylene was detected in Hell's Canyon Resort Marina, Federal Navigation Channel, and Port of Clarkston. The detections reported 23 ppb, which is just above the detection limit of the method. With a screening level of 560 ppb no biological effects were anticipated.

Benzo (a) anthracene was found only in the Federal Navigation Channel and averaged 22.6 ppb. With a screening level of 1,300 ppb no biological effects were anticipated.

Benzo (b) floranthene was found in Hell's Canyon Resort Marina and the Federal Navigation Channel and averaged 44.6 ppb. There was no screen limit provided for this poly nuclear aromatic hydrocarbon.

Benzo (g, h, I) perylene was detected in the Federal Navigation Channel and averaged 17.4 ppb. With a screening level of 670 ppb no biological effects were anticipated.

Chrysene was found in the Hell's Canyon Resort Marina, Federal Navigation Channel, and Port of Lewiston. The maximum value detected was located in the Idaho portion of the Federal Navigation channel (57.3 ppb). Other areas to be dredged where chrysene was detected averaged 42.2 ppb. With a screening level of 1,400 ppb no biological effects were anticipated.

Fluoranthene was found in Hell's Canyon Resort Marina and in the Idaho portion of the Federal Navigation Channel. Hell's Canyon Resort Marina averaged 22 ppb and the Navigation Channel had a single detection at 52.7 ppb. With a screening level of 1,700 ppb no biological effects were anticipated.

Flourene was found in the Federal navigation Channel only and averaged 68.2 ppb. With a screening level of 540 ppb no biological effects were anticipated.

Ideno (1,2,3-c, d) pyrene was found only in Idaho, both in the Port and Navigation Channel with an average of 8.6 ppb. With a screening level of 600 ppb no biological effects were anticipated.

Napthalene was found only in the Federal Navigation Channel and averaged 49.4 ppb. With a screening level of 2,100 ppb no biological effects were anticipated.

Phenanthrene was found only in the Federal Navigation Channel and averaged 21.2 ppb. With a screening level of 2,100 ppb no biological effects were anticipated.

Pyrene was found in the Hell's Canyon Resort Marina and in the Idaho portion of the Federal Navigation Channel. The median result was 29.8 ppb with a single measurement of 68.7 ppb in the Clearwater River, Idaho. With a screening level of 2,600 ppb no biological effects were anticipated.

The dioxins and furans congeners analyzed using EPA method 8290 were as follows: (none were detected at levels which would require bioassay testing under the Lower Columbia Framework criteria.

Table H-17 List of Compounds Analyzed with Method 8290

1,2,3,4,7,8-Heptachlorodibenzo-p-dioxin	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	1,2,3,6,7,8-Hexachlorodibenzofuran
1,2,3,6,7,8-Hexachlorodibenzofuran	1,2,3,7,8-Pentachlordibenzo-p-dioxin	1,2,3,7,8-Hexachlorodibenzo-p-dioxin
1,2,3,7,8,9-Hexachlorodibenzofuran	1,2,3,4,6,7,8-Heptachlorodibenzofuran	2,3,4,6,7,8-Hexachlorodibenzofuran
2,3,4,7,8-Pentachlorodibenzofuran	Octachlorodibenzo-p-dioxin	Octachlorodibenzofuran
2,3,7,8-Tetrachlorodibenzo-p-dioxin	2,3,7,8-Tetrachlorodibenzofuran	Total TCDD
Total TCDF	Total HPCDD	Total HPCDF
Total HXCDF	Total HXCDD	Total PECDD
Total PECDF		

Dioxin/furan congeners were found in Hell's Canyon Resort Marina and in the Washington State portion of the Federal Navigation Channel. Twenty-five sediment samples in the areas to be dredged were analyzed using EPA method 4425 (P450 Human Reporter Gene System). Of these samples, 10 reported positive detection of a "Dioxin-PAH like compound". Since all samples were pre-extracted, those samples with a positive were analyzed with the EPA 8290 test method for the confirmatory information. The following congeners were found at seven of 10 samples analyzed by high-resolution gas chromatograph mass spectrometry: Octachlorodibenzo-p-dioxin (8.0 to 162 ppt); 1,2,3,4,7,8-Heptachlorodibenzo-p-dioxin (0.7 to 22 ppt); 1,2,3,4,6,7,8-Heptachlorodibenzofuran (0.2 to 2 ppt); and Octachlorodibenzofuran (0.3 to 19 ppt). The congener 2,3,4,6,7,8-Hexachlorodibenzofuran was found in 4 of the 10 samples analyzed ranging from 0.12 to 1.15 ppt. The congener 1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin found in two samples that resulted in 1.3 to 1.4 ppt respectively. No TCDD was found during this sediment chemical survey. Toxic equivalency quantification (TEQ) calculations for each sediment sample location were performed with resulting TEQs ranging from 0.018 to 0.060 ppt in the areas to be dredged. The Lower Columbia Framework uses the Puget Sound Dredged Disposal Analysis (PSDDA) guidelines for Dioxin TEQ. The screening criteria bioaccumulation trigger is currently set at 15 ppt. The sediments to be dredged by this action were 100 times less than the trigger and should have no significant impact to biota.

The Herbicide compounds analyzed using EPA method 8141 were as follows: (all were below the Lower Columbia Framework screening criteria.

Table H-18 List of Compounds Analyzed with Method 8141

Bolstar	Diethylphosphorodithioic acid	Chlorpyrifos
Coumaphos	Demeton	Diazinon
Dichlorvos	Disulfoton	Ethoprop
Fensulfothion	Fenthion	Methyl parathion
Mevinphos	Parathion	Ronnel
Stirfos	Tokuthion	Trichloronate

The herbicide compounds that were below detection limits were; Diethylphosphorodithioic acid; Bolstar; Chlorpyrifos; Coumaphos; Demeton; Diazinon; Dichlorvos; Disulfoton; Ethoprop; Fensulfothion; Fenthion; Methyl parathion; Mevinphos; Parathion; Ronnel; Stirfos; Tokuthion; and Trichloronate.

The organo-phosphate pesticide compounds analyzed using EPA method 8151A were as follows: (all were below screening limits under the Lower Columbia Framework.

Table H-19 List of Compounds Analyzed with Method 8151A

2,4-D	2,4-DB	Phorate (Thimate)
Acifluorfen-sodium (Blazer & Tackle)	4-NITROANISOLE	Silvex
Bentazon	Chloramben	Dalapon
Dicamba	Dichlorprop	Dinoseb
2-Methyl-4-chlorophenoxyacetic acid	2-(2-Methyl-4-chlorophenoxy) propian	Pentachloroanisole
Picloram		

The organo-phosphate pesticide compounds below detection limits were; 2,4-D; 2,4-DB; 4-NITROANISOLE; Pentachloroanisole; Acifluorfen-sodium (Blazer & Tackle); Bentazon; Chloramben; Dalapon; Dicamba; Dichlorprop; Dinoseb; 2-(2-Methyl-4-chlorophenoxy) propian; Phorate (Thimate); Silvex; and Picloram.

The list of metals analyzed using EPA method 6010 were as follows:

Table H-20 List of Metals Analyzed with Method 6010

Aluminum	Antimony	Barium
Beryllium	Cadmium	Calcium
Chromium	Cobalt	Copper
Iron	Lead	Magnesium
Manganese	Molybdenum	Nickel
Potassium	Sodium	Vanadium
Zinc	Arsenic	

Antimony samples were all below framework reportable quantities of 1 ppm. With a screening level of 150 ppm no biological effects were anticipated. Arsenic samples were analyzed but were not reported because of problems with the contract lab. Arsenic levels averaged 5.3 ppm in the Lower Granite LSRF study samples. Since the minimum screening limit is 57 ppm, it was decided not to rerun arsenic tests in the navigation channel. The highest cadmium result was found in Federal Navigation Channel at 1.06 ppm. With a screening level of 5.1 ppm no water quality effects were anticipated. No bioaccumulation criterion is available for cadmium. Copper was detected throughout the entire range of samples. The highest result at 44.3 ppm was found in the Green Belt Boat Basin. The Hell's Canyon Resort Marina averaged 10.4 ppm. Copper was found in the other areas to be dredged but was mostly below 10 ppm. The screening level for copper was 390 ppm. The copper levels in the samples were similar to what is found in Eastern Washington background levels. No information on Idaho background levels for metals

was available. Lead was present in all sediment samples. The highest concentration found was in the Federal Navigation Channel at 8.35 ppm. The Lower Columbia Framework provides a screening level of 450 ppm for lead but does not have bioaccumulation criteria for lead. Nickel was found in all sediment samples. The highest level (12.1 ppm) was detected in the Green Belt Boat Basin. With a screening limit of 140 ppm nickel was not considered to present any ecological risk. Silver was not analyzed and no data is available for this metal. Zinc sample results ranged from non-detect to 37.9 ppm in the Federal Navigation Channel as compared to a screening level of 410 ppm. Hollebeke habitat management unit averaged 34 ppm but all other sampled areas demonstrated uniformity in the distribution and abundance of zinc in the sediments. Aluminum was one of the most abundant metals found in the sediments. The highest concentration was found was in the Idaho portion of the Federal Navigation Channel (7,885 ppm). The Lower Columbia framework does not consider Aluminum to be harmful to aquatic life or humans at any level and therefore no screening level or bioaccumulation limit is set. Barium was found in all sample sites with the highest sample recorded (99.6 ppm) in the Idaho Federal Navigation Channel. Beryllium was not found above detection limits in any of the samples. Barium and Beryllium are not considered to be harmful at any concentration by the Lower Columbia framework. Calcium was found in all samples with the highest reading (3,019 ppm) in the Green Belt Boat Basin. This alkali earth element is not a contaminant, however the great abundance of the element does contribute to the explanation of the alkaline pH in the Snake River as naturally occurring. Chromium was found in all the sample stations. The highest concentrations found were in the Idaho Navigation Channel and at the Hollebeck HMU intake with a reading of 8.83 ppm and 8.81ppm respectively. The Lower Columbia framework does not consider chromium to be a contaminant and therefore no screening level or bioaccumulation trigger is provided. Cobalt was found in all samples with the highest reading found at Willow Landing at 8.29 ppm. The Lower Columbia framework does not consider cobalt to be a contaminant and therefore no screening level or bioaccumulation trigger is provided. Iron was very abundant in the sediments with approximately 1/3 of all sample measurements in excess of 10,000 ppm. Since iron is a necessary micronutrient, a trace amount of it is required for aquatic life health. Iron has no screening level. There should be more than an ample supply of this element available for most organisms. Magnesium was found in all samples with the highest quantity found in Hell's Canyon Resort Marina at 405 ppm. . The Lower Columbia framework does not consider magnesium to be a contaminant and therefore no screening level or bioaccumulation trigger is provided. Manganese concentrations were high in most samples. The highest recording was 4,009 ppm in the Hollebeke HMU. The Lower Columbia framework does not consider manganese to be a contaminant and therefore no screening level or bioaccumulation trigger is provided. Molybdenum was not found above detection limits in any of the samples. Vanadium was found in all samples tested. The highest reading was found in the Green Belt Boat Basin at 65.2 ppm. Potassium and sodium are important micronutrients for maintaining viable invertebrate communities in trace amounts. Potassium and sodium have no screening levels. Most sample results for potassium were in excess of 1,000 ppm and the sodium levels were in slight excess of 100 ppm. This ratio is considered to be normal for fresh water sediments in most cases.

All samples were sieved to determine if less than 20% silts and clays (Wentworth size classification) were present in the material. Total organic carbon percentages of sediment samples were determined using EPA method 9060. These same samples were also analyzed for

their percent by weight of total dissolved solids. Table H-21 presents a comparison of the three constituent properties used to determine if further tier two chemical testing was required:

Table H-21 Constituent Properties of Samples from the Proposed Dredging Sites

	% By weight pass thru US No. 230 *	% Total Organic Carbon (TOC)	% By Weight volatile solids
Fed Navigation Channel (WA)	0.38 to 39.5	<0.1to 2.89	<5.0 to 17.2
Fed Navigation Channel (ID)	0.09 to 4.87	0.12 to 12.7 (Petroleum high)	<5.0 to 21.3
Port of Lewiston	30.0 to 32.2	0.18	<5.0
Port of Clarkston	~ 20%	0.36	5.1
Hell's Gate Marina	21.7 to 31.0	2.89 to 3.17	10.9 to 21.2
Green Belt Boat Basin	31.0 to 37.3	1.89 to 3.13	15.1 to 21.7
Illia Boat Basin	>25.6%	0.44%	15.1
Willow Landing	19.0 to 25.5	0.66 to 1.07	30.1
Swallows Beach	18.0 to 38.2	> 2.9	20.9 to 21.3
Hollebeke HMU	21.1 to 30.6	0.56 to 0.93	24.0 to 28.8

* The US 230 sieve separates sand and gravel from fine-grained soils such as silt or clay.

Samples from the navigation approach dredging template recovered 99.99% by weight Wentworth-classified pebble and cobble gravels. With this information no further testing was required of these areas to be dredged.

The Herbicide Glyphosate (Roundup, Rodeo, and other trade names) and its degradation product AMPA were analyzed by high performance liquid chromatography. The breakdown product AMPA was not found above detection limits. A single Glyphosate detection of 23 ppb was discovered in the Green Belt Boat Basin. This was the only quantifiable above detection limit result out of 36 samples analyzed for Glyphosate. Although it is used very heavily in this local area, Glyphosate has a 6-month half-life and is an emergence herbicide. It is not anticipated to be present in measurable levels during the winter work window.

Total mercury was analyzed using the EPA 7471 cold vapor method. There were no mercury detections above soil detection limits (1 ppm) during this sediment quality survey. The screening criterion is less than 1 ppm (0.41ppm) but the bioaccumulation trigger is 1.5 ppm. The results do not completely identify if mercury is above screening levels or not. Since the data did not exceed bioaccumulation limits, it was not necessary to proceed with bioassay testing. Better equipment (lower detection quantification) and technique is available commercially at this time. Any future testing would use more sensitive tests (by an order of magnitude) since the screening and bioaccumulation limits are so close.

The oil and grease parameter was analyzed using EPA method 9071. The interim Lower Columbia testing framework does not consider petroleum products a contaminant and no screening levels are available from the framework. The analysis was conducted to evaluate the material's suitability as a habitat for aquatic species.

3.3 SUMMARY OF RESULTS

Ten potential areas to be dredged were evaluated in this phase II, pre-dredge sediment evaluation. In addition to the sediment evaluation, baseline summary water quality data was included in this phase II evaluation. The general water quality as measured by primary productivity was determined to be meso or hyper eutrophic since nutrient quantities are fairly or greatly abundant. The reservoir production is clearly limited by phosphorus abundance (table H-15). The primary water quality problem associated with dredging is an overabundance of ammonia in sediments and the amount readily released to the environment during the activity. The natural temperature and pH condition of the water exacerbates the ammonia problem. By dredging during a winter work window when the water temperatures are cold, there is a low risk of impacting aquatic life, their reproductive cycles, and ecology on the macro scale.

Anthropogenic organic compounds were evaluated using the EPA test methods: 8270C (semi-volatile compounds), 8290 (dioxins and furans), 8141 (herbicides), 8151A (organo-phosphate pesticides), 9071 (oil and grease), and 547 (Glyphosate). These organic compounds were evaluated using the Puget Sound Sediment Disposal Procedures and the Lower Columbia (Portland District) Evaluation Framework screening and bioaccumulation limits. In addition, other protection criteria guidelines such EPA safe drinking water and EPA Protection of Aquatic Life Criterion were reviewed as well. Some dioxin and furan congeners were detected but were 100 times below the Puget Sound Disposal bioaccumulation trigger. Glyphosate was present in many samples but did not exceed drinking water standards. The other organic compound detections were PAH compounds. None of the PAH compounds were found to exceed the screening limits.

Twenty-one elemental metals were examined using EPA method 6010. For the metals that had screening and bioaccumulation limits, all results were below the recommended screening values. Manganese does not have a screening criterion under the interim protocols used. However, throughout the entire Lower Snake River, manganese was found in past and present samples in high concentrations. Mercury laboratory detection limits were very close to the bioaccumulation trigger. None of the samples evaluated for the potential areas to be dredged detected mercury. Arsenic laboratory results were not usable for this investigation. The Tier one data indicates the average arsenic concentrations were 10 times below the screening limit. Therefore, it was not necessary to repeat the tier two based on the available tier one data.

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